Hamburg University of Applied Sciences

Faculty of Life Sciences

Efficacy of intravenous induction of general anesthesia at BC Children's Hospital – a prospective audit and identification of factors for success

Bachelor's Thesis

Biomedical Engineering

Author:
Celine HÜGEL
[redacted]

Examiners:
Prof. Dr. Bernd KELLNER
Prof. Dr. Matthias GÖRGES

Hamburg, June 26, 2019

Celine Hügel

Efficacy of intravenous induction of general anesthesia at BC Children's Hospital – a prospective audit and identification of factors for success

Bachelor's thesis conducted at
Pediatric Anesthesia Research Team,
BC Children's Hospital Research Institute,
BC Children's Hospital,
submitted in fulfillment of the requirements for the degree of B.Sc.
Biomedical Engineering at
Hamburg University of Applied Sciences
Faculty of Life Sciences
First examiner: Prof. Dr. Bernd Kellner (Hamburg University of Applied Sciences)
Second examiner: Prof. Dr. Matthias Görges (Pediatric Anesthesia Research Team)

Declaration of Authorship

[1.5cm]

I warrant that the thesis is my original work and that I have not received outside assistance. Only the sources cited have been used in this draft. Parts that are direct quotes or paraphrases are identified as such.

[redacted] [redacted]

Hamburg, (date) *Signature*

I hereby grant the Hamburg University of Applied Sciences the right to publish, reproduce, and distribute my work, especially when it is to be presented to a third party for inspection.

[redacted] [redacted]

Hamburg, (date) *Signature*

Abstract

The anesthesia department at BCCH, a tertiary pediatric centre in Vancouver, Canada, conducts IV cannulation for induction of anesthesia in awake children as an institutional policy, predominantly without anxiolytic premedication. An observational study of IV cannulation success in the operating rooms of BCCH was conducted over a one-month period at regular operating room capacity. The primary outcome was to identify the success rate of IV cannula placement in awake children in ≤ 2 attempts. For each case, basic demographic information, details about the setting in which the IV cannulation was performed, IV insertion characteristics, distraction techniques, behavior of the child, number of insertion attempts and success/failure were captured. Additionally, attending anesthesiologists and procedural suite nurses participated in semi-structured interviews to document key facilitators ensuring success of the IV cannulation attempt, barriers, effective distraction techniques, and teaching approaches.
Data from 984 cases were summarized and plotted in MATLAB. A logistic regression model for successful IV inductions was designed and reduced using the Akaike information criterion optimization in R. The local BCCH IV induction bundle was successful in 90 % of patients who required cannulation for planned IV induction. A majority of 90 % had no or only minimal reaction to IV insertion; completely pain- and reaction-free IV insertion was achieved in 64 %. Predictors for success included older age of the pediatric patient and their behaviour at first encounter.
Qualitative interview data of 13 participants were analyzed using a thematic approach in NVivo. Analysis of interview data was conducted in four phases: organizing, coding, categorizing, and theme development. Several factors for success were identified, inter alia effective distraction, preparation of the family to expect IV induction, effective use of local analgesic ream, and selectivity in consideration of IV induction appropriateness. Barriers included needle phobia, anxious or uncooperative parents, ineffective use of analgesic cream, and unfavourable anatomy. Distraction techniques highly depended on the age and developmental stage of the patient. Participants advised novices to practice on adults and sleeping children first, before attempting an IV start in an awake child.
Results suggest that IV induction of anesthesia for a large majority of patients is feasible, when implemented as an institutional strategy. Results of this study further show that IV induction is possible without unduly traumatizing pediatric patients.

Acknowledgements

I wish to thank all participating anesthesiologists, anesthesia assistants, and operating room nurses.

Contents

List of Figures

List of Tables

List of Abbreviations

ACU Anesthetic Care Unit

AIC Akaike information criterion

BCCH BC Children's Hospital

BCCHR BC Children's Hospital Research Institute

BSA body surface area

CI confidence interval

ED emergency delirium

EEG electroencephalography

ICU Intensive Care Unit

IH inhalational

IQR interquartile range

IV intravenous

MGH Massachusetts General Hospital

MRI Magnetic Resonance Imaging

MWW Mann-Whitney-Wilcoxon

OR operating room

PACU Post-Anesthetic Care Unit

PONV postoperative nausea and vomiting

PPIA parental presence at induction of anesthesia

PRIS propofol-related infusion syndrome

REB Research Ethics Board

REDCap Research Electronic Data Capture

SV spontaneous ventilation

TCPS2 Tri-Council Policy Statement 2

TIVA total intravenous anesthesia

UBC	University of British Columbia
VA	vascular access
VR	Virtual Reality

1 Introduction

1.1 History of Pediatric Anesthesia

Pediatric anesthesia has evolved from adult anesthesia practice by adapting techniques and equipment to pediatric patients. It has advanced enormously since first control over pain, sensation, consciousness, and motion was gained in the 19th century (Smith and Rockoff, 2006). Today, pediatric anesthesia is one of the most popular fields for specialized training.

"Gentlemen, this is no humbug!" declared the operating surgeon on October 16, 1846 after William T. G. Morton, a young Boston dentist, performed the first successful public demonstration of ether anesthesia in a patient undergoing surgery. This historic event in the operating theatre of Massachusetts General Hospital (MGH) in Boston, which is now known as Ether Dome, is considered to mark the birth of modern anesthesia (see Fig. 1) (Morgan Jr., Mikhail, and Murray, 2008b).
Within the first year after Morton's demonstration four of five pediatric patients undergoing surgery at MGH received ether anesthesia, although little was known about its dangers, mechanism of actions, or how to dose it (Costarino and Downes, 2005). It soon became apparent that children were more likely to have complications related to ether, such as high incidence in nausea and vomiting after anesthesia. Also flammability, prolonged induction time and the unpleasant and persistent odor of ether kept the search for a better anesthetic ongoing (Robinson and Toledo, 2012).
The administration of ether with a handkerchief was typically delegated to non-physicians in the United States, partly due to ether's relatively safe anesthetic profile and the belief that this was a trivial service that any person could perform. The administration as a medical activity therefore rarely aroused interest of physicians and nurses eventually took over responsibilities in this special field (Morgan Jr., Mikhail, and Murray, 2008b; Smith and Rockoff, 2006).
In the United Kingdom, chloroform was first used on January 19, 1847 by the Scottish obstetrician James Young Simpson. Chloroform gained acceptance after the English anesthetist John Snow administered the anesthetic to Queen Victoria during the delivery of her eighth child (Costarino and Downes, 2005). Snow used chloroform on several hundred children and neonates in the following years, stating that *"Chloroform acts very favorably on infants and children"* (Mai and Coté, 2012). With various advantages, including increased potency compared to ether, faster onset of action, more pleasant sensations, sweet odor, and being non-flammable, chloroform is superior to ether in capable hands. However, high incidences of hypotension, respiratory depression, and cardiac arrest also occurred during its administration, also reports of death due to hepatotoxicity sparked concerns. This eventually lead to a waning use of chloroform (Robinson and Toledo, 2012). A dictum throughout the British Empire was established, that only allowed physicians the administration of anesthesia, resulting in anesthesia as a thriving medical specialty. Although other inhalational anesthetics were introduced throughout the rest of the century (ethyl chloride, ethylene, etc.), ether remained the standard general anesthetic until early 1960s (Morgan Jr., Mikhail, and Murray, 2008b).

The first administration of intravenous anesthetics (opium with alcohol), thus first conduction of total intravenous anesthesia (TIVA), followed by long-term recovery, took place in 1656 in a dog. TIVA is defined as technique of general anesthesia, in which anesthetic agents are exclusively given by the intravenous route for induction and maintenance of anesthesia. Due to a lack of equipment for intravenous (IV) access, difficulty in dose titration, and death due to ventilator failure, among other factors, this technique was not readily translatable to clinical practice in humans (Dorrington and Poole, 2013). In 1853, the Scottish physician Alexander Wood invented the first hypodermic syringe and needle, allowing for administration of opium or morphine via the subcutaneous route (see Fig. 1). However, the challenge of venous access, lack of understanding of dose-response effects and titration of drug dosage, among other barriers, prevented an early widespread adoption of TIVA. Thus, inhalational anesthesia has dominated the anesthetic practice since its emergence (Lauder, 2015).

In the late 19th century, progress was made in airway control. The American pediatrician Joseph P. O'Dwyer (1841-1898) accomplished the first successful endotracheal intubation on May 21th 1884 by blindly passing a metal "O'Dwyer" tubes into the trachea in order to maintain sufficient ventilation in patients with diphtheria (see Fig. 1) (Robinson and Toledo, 2012). With endotracheal intubation becoming increasingly common, more efficient techniques of placing the tube were needed. The first laryngoscope, a U-shaped tool, was therefore invented in the beginning of the 20th century and further modified in the following years. Pediatric sized laryngoscopes and endotracheal tubes were not readily available until the late 1920s (Mai et al., 2014). In 1937 Professor Sir Robert R. Macintosh developed a shorter and continuously curved blade and introduced a breakthrough technique; both of which are still in practice today (see Fig. 1) (Robinson and Toledo, 2012; Scott and Barker, 2009; Burkle et al., 2004).

Progress was made slowly by trial and error in the beginning of the 20th century. Before the 1940s pediatric patients were cared for in an environment equipped for adults and were treated like "little men". Anesthesia was dangerous for many reasons: understanding of pediatric physiology was crude, poor anesthesia equipment with instruments not optimized for pediatric use were used, there was little ability to provide vascular access, no understanding of resuscitation techniques, primitive surgical techniques, and antibiotics did not exist (Smith and Rockoff, 2006; Costarino and Downes, 2005). By 1940 the abilities of anesthesiologists were sufficient enough to create quite satisfactory operating conditions for surgeons.

Between 1940 and 1960 advances in several areas, particularly cardiovascular control, assisted and controlled respiration, and thermal control were achieved, involving the work of both anesthesiologists and surgeons, allowing for longer and more extensive procedures. During the 1940s and 1950s positive pressure ventilators became available, replacing the negative pressure ventilators ('iron lung') (Kacmarek, 2011). The 'iron lung' (see Fig. 1) was widely used during the worldwide reoccurring poliomyelitis epidemics from 1930 to 1960. To manage the large number of patients requiring ventilatory support, the first Intensive Care Units (ICUs) were established (Kacmarek, 2011; Kelly et al., 2014).

With accelerating activities in pediatric anesthesia, the child's fear of anesthesia became more obvious and concerns were raised by psychologists, pediatricians, anesthesiologists, and many others between 1945 and 1953. Thus, increased attention has been paid to premedication with morphine and the use of intramuscular barbiturates. However, drug dosage estimated by age and/or weight remained an unsolved problem with consequences of either ineffective agents or an unpredictable

degree of sedation. With repeated failure of sedative agents, close interest in each child undergoing anesthesia grew. Anesthesiologists eventually developed greater skills to gain the confidence of children in preoperative visits and to divert their attention at induction (Smith and Rockoff, 2006).
In the 1950s the establishment of recovery rooms, also called Post-Anesthetic Care Units (PACUs) accelerated. First teaching centers were established throughout Europe and North America attracting both novice and experienced anesthesiologists. Clinical training was given in basic, safe, and practical methods of anesthetic control of pediatric patients undergoing standard operations, as well as special methods for those at higher risk. Despite increased communication between teaching centers in the field of pediatric anesthesia, there has been little space, time or funds for research (Smith and Rockoff, 2006).

In 1956 halothane, a non-flammable anesthetic agent, was introduced clinically, ending the era of popular flammable anesthetics. With both halothane and advanced delivery systems becoming available, the safety of anesthesia improved dramatically (Robinson and Toledo, 2012; Costarino and Downes, 2005).

From 1960 to 1980 non-flammable anesthetic agents gave way for rapid and extensive advances in all areas of pediatric anesthesia, particularly in the development of electronic devices for monitoring and physiologic control: Doppler sonography for the measurement of blood pressure in infants became available as well as arterial oxygen saturation measurement. Measurements of arterial blood gas, blood sugar, hemoglobin, electrolytes and other entities were evaluated in laboratories and intraoperatively. Standard monitoring equipment has not only become smaller for very young patients, but also quite extensive and sophisticated by including continuous pulse oximetry and the introduction of capnography as a standard for basic anesthetic monitoring (see Fig. 1) (Saha, 2012).
During this time, the practice of anesthesiologists focused on greater precision and "control by the numbers" (Smith and Rockoff, 2006). The insertion of arterial and central venous catheter became commonplace; fluid, electrolyte, and blood replacements were more widely adopted. Surgical progress was made with breakthroughs in infant cardiac surgery and renal transplantation, requiring anesthesiologists to manage prolonged anesthetic maintenance, fluid and blood loss. Consequently, responsibilities of anesthesiologists not only included pre- and intraoperative management, but also postoperative care for patients during the recovery period. PACUs finally became mandatory providing highly trained personnel and equipment for high-risk patient care (Smith and Rockoff, 2006).
By the end of the 1970s teaching facilities, providing special training in pediatric anesthesia, were fully established, residency training programs were accredited and research in various areas intensified. However, premedication with sedatives was still unpredictable and only little progress was made in the control of fear, primarily by granting parents' permission to attend to the child's bedside and induction areas.

From the 1980s on pediatric facilities grew rapidly all over the world, enabling specialized care for younger and younger children with more advanced equipment and more highly trained staff. A change in practice took place during this time with the evaluation of pediatric patients in preoperative clinics, instead of being admitted prior to the day of the procedure. Procedures are increasingly being conducted in an ambulatory setting with patients being discharged the same day. The duties of pediatric anesthesiologists were further expanding from the operating room to

non-surgical procedures, such as medical imaging procedures requiring extended periods of immobilization. In 2002 several policy statements were released by the American Academy of Pediatrics emphasizing the need for proper personnel and facilities whenever pediatric patients require surgery and/or anesthesia (Smith and Rockoff, 2006).
New potent anesthetic agents for inhalational anesthesia were developed and replaced halothane. Isoflurane was released in 1981, followed by desflurane (1992) and sevoflurane (1994). Due to its safety, efficacy and smooth induction properties (it is less irritating to the airway than the other halogenated ethers), sevoflurane is predominantly used today for inhalational anesthesia (Smith and Rockoff, 2006).

TIVA did not become widely used until the introduction of propofol to clinical use in 1977, or rather in 1986 when an improved formulation of propofol was introduced. The former was withdrawn from the market due to anaphylactic reactions caused by its initial formulation/solvent (Dorrington and Poole, 2013; Chidambaran, Costandi, and D'Mello, 2015). Propofol, with its rapid effect and favourable recovery profile, soon became the most commonly applied induction agent, even if followed by inhalational maintenance. In the 1990s, several clinical trials and case series established its use for induction and maintenance of general anesthesia in children (Chidambaran, Costandi, and D'Mello, 2015). New developments were also made with "descendants" of fentanyl, such as the release of remifentanil, which is used as an adjunct to propofol. To ease the discomfort of venipuncture, topical analgesic creams, such as an eutectic mixture of lidocanie and prilocaine (EMLA) or teracaine (Ametop), have been developed (Smith and Rockoff, 2006). Since the 1980s, greater attention has been paid towards pain control/treatment and the psychological impact of anesthesia for pediatric patients. Measures to assess and decrease preoperative fear and anxiety were increasingly implemented (Smith and Rockoff, 2006).

Today, extended research reaches a new level of excellence and productivity to advance the practice of anesthesia through new knowledge, hence improving patient care. Pediatric pain medicine, pediatric intensive care, and pediatric cardiac anesthesiology are recognized and well-established subspecialties within the field of pediatric anesthesia. New subspecializations continue to emerge, such as neonatal anesthesia. The challenges in the field of pediatric anesthesia are ongoing due to more complex surgical and diagnostic techniques, performed in ever younger patients (Smith and Rockoff, 2006).

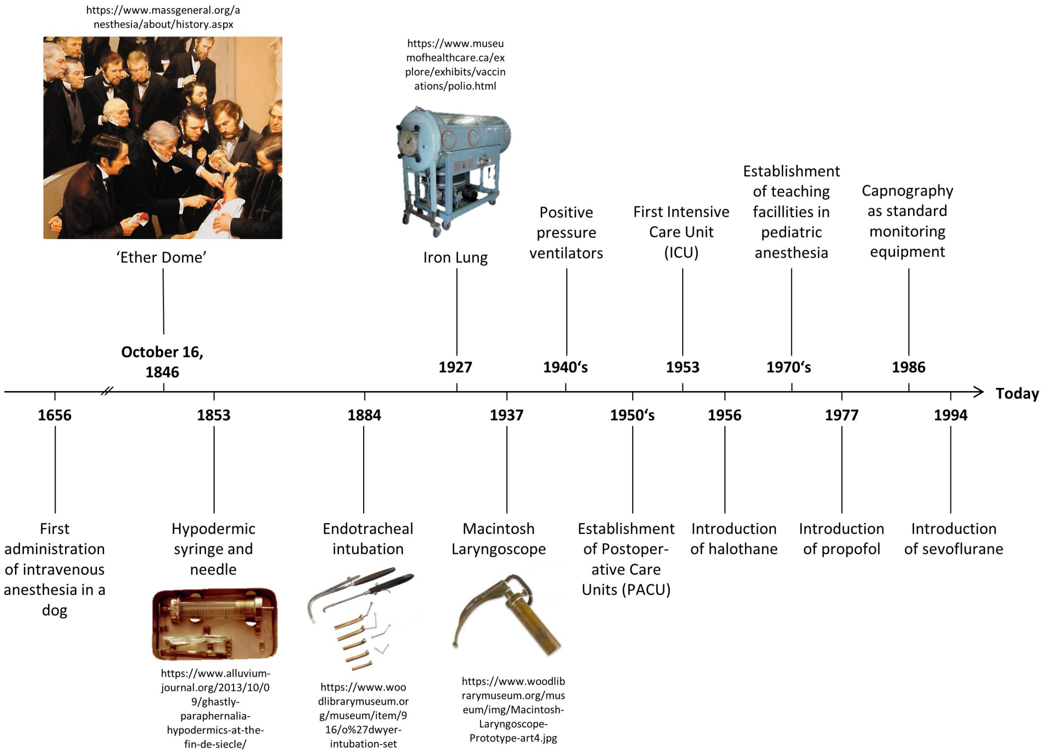

FIG. 1. Milestones in the history of anesthesia

1.2 Medical Consideration

This chapter will focus on the special characteristics of pediatric anesthesia and the two most common methods of induction of general anesthesia, inhalational and intravenous anesthesia. Also, advantages and disadvantages of TIVA and its pharmacology are further elaborated upon.

1.2.1 Special characteristics of pediatric anesthesia

The needs of neonates (birth to 1 month), infants (1 month to 2 years), children (2 to 12 years) and adolescents (12 to 21 years) regarding general anesthesia vary considerably between the age groups and are fundamentally different from those of adults (Motoyama and Davis, 2006). This can be explained by anatomic and physiologic differences, differences in response to pharmacological agents as well as psychological differences. To enable safe anesthetic management, and control of vital body functions despite the loss of homeostasis, modifications of anesthetic equipment and special qualities of the anesthesiologist in the practice of pediatrics are required.

1.2.1.1 Anatomic and physiologic differences The pediatric population undergoes anatomical and physiological changes during their development to adulthood. Differences in body size and relative proportions, as well as differences in respiratory, cardiovascular, and central nervous system responses are further explained below and based on the books "Smith's Anesthesia for Infants and Children (Motoyama and Davis, 2006) and "Manual of Pediatric Anesthesia" (Lerman, Coté, and Steward, 2016a).

Body size and proportions: Body proportions of pediatric patients also differ from those of adults; due to a proportionally larger body surface area (BSA) relative to weight and a lack of heat insulating subcutaneous fat in neonates, the risk of heat loss is greater (Lerman, Coté, and Steward, 2016c). This is important with regard to general anesthesia since it inhibits thermoregulation, which may result in hypothermia if not corrected appropriately by the anesthesiologist.

Airway management: Management of the pediatric airway is more difficult than in adults. Neonates and infants have a proportionally large tongue, narrow nasal passages, and a short neck and trachea. Airway obstruction and pharyngeal airway collapse are more likely in this population due to the anatomy of the airway and extremely sensitive upper airway muscle tone, which is more easily depressed by general anesthesia. Both a large head and a short neck relative to body size result in the chin resting on the chest in supine position. Thus, positioning for the laryngoscopy is difficult and may be eased by placing some sort of support (e.g. towel) underneath the shoulders of the patient, to achieve a more natural position and open up the airway (Harless, Ramaiah, and Bhananker, 2014).

Respiratory system: The lungs are not fully mature at full-term birth. The respiratory rate in neonates is elevated and progressively reduces to adult values by adolescence. Under anesthesia, the functional residual capacity is reduce due to abolished muscle tension, whereas the metabolic rate is increased. Also, the thorax and chest wall is very compliant. Thus, continuous positive airway pressure or positive end-expiratory pressure is needed to maintain ventilation.

Cardiovascular system: From birth to adolescence, both systolic and diastolic blood pressure progressively increases, whereas heart rate progressively decrease. Neonates and infants are very sensitive to volatile anesthetics, hypoxia and acidosis. Due to reduced compliance of the neonates' ventricle, the size of the stroke volume is limited. Thus, in order to change the cardiac output, the heart rate must change.

Central and autonomic nervous system: The central nervous system is still in development after birth, whereas the autonomous nervous system is already well developed. Protective responses, such as laryngeal reflex and baroreflex (to maintain blood pressure and heart rate), are well functioning. The former is highly potent and can result in cardiac arrest due to bradycardia induced by hypoxemia.

1.2.1.2 Differences in response to pharmacologic agents Drug dosage in children is typically based on the patient's weight in kilogram. However, this calculation does not take disproportional development and growth of the organ systems of pediatric patients during childhood into account, resulting in differences in uptake, distribution, metabolism, and elimination of drugs, including anesthetics. Physiologic differences and variables such as increased blood flow, decreased protein binding, or higher metabolic rate, among others, are considered individually to ensure reliable performance of drugs in pediatric patients (Morgan Jr., Mikhail, and Murray, 2008a). This is particularly important in neonates and infants since they are the furthest away in terms of development from adults (Batchelor and Marriott, 2015). For instance, the total water content in neonates is higher than in adults (70-75% vs. 50-60%), resulting in a higher dose and volume of distribution and clearance rate for most intravenous drugs in infants (Morgan Jr., Mikhail, and Murray, 2008a; Lerman, Coté, and Steward, 2016b). However, this does not apply to infants under one year of age and neonates; in this population the clearance rate is dramatically decreased as a result of the maturation of the liver enzyme system (Lauder, 2015; Lerman, Coté, and Steward, 2016b).

1.2.1.3 Psychological differences Since 1980 increased attention has been paid to the psychological needs of hospitalized children and the emotional consequences of general anesthesia and surgery. The level of stress and anxiety is not only depending on patient-related factors, such as age, maturity and personality, past surgical experiences, individual capacity for affect regulation and anxiety, parental trait anxiety, etc., but also on environmental conditions, such as unfamiliar environment and exposure to strangers, interactions with medical staff, number of medical personnel interacting with the patient, noise level, intensity of lights, etc. (Motoyama, Gronert, and Fine, 2006).

Age plays a key role in assessing the patient's needs and extend of emotional stress. Neonates and infants under six months of age are not afraid of strangers. Preschool-age children between one to five years are both young enough to be dependent on their parents and old enough to recognize the parent's absence. Consequently, separation from parents is the most intense fear in this age group. It is difficult for them to understand the need for a procedure and the procedure itself, which is why these children show the most severe impact on behaviour after hospitalization. These include sleep disorders, nightmares, apathy, eating disorders, and separation anxiety (Bortone, La Colla, and Astuto, 2016). In school-age children (six years or older) the experience of pain and discomfort associated with the procedure represent the greatest upset. Adolescents are usually more concerned about anesthesia in general, particularly the loss of self-control when forcefully put to sleep or waking up during the surgery (Lerman, Coté, and Steward, 2016c; Motoyama and Davis, 2006).

Additional factors contributing to the development of preoperative anxiety are poor-quality medical encounters in the past, high trait anxiety, a shy and inhibited temperament, and the lack of developmental maturity and social adaptability. Parental anxiety strongly affects the child's distress before surgery; parents, who are more anxious themselves are less available to respond effectively to their child's needs (Kain, 2006). Another factor influencing the patient's emotional response is prolonged hospitalization. The individual concerns are addressed appropriately, since it can cause temporary or lasting damage to the psychosocial development of the pediatric patient (Motoyama and Davis, 2006). Both preoperative psychological preparation, including prehabilitation, and the role of the anesthesiologist are important to recognize, evaluate and ease the level of anxiety.

1.2.2 Methods of induction

There are multiple routes to safely induce general anesthesia in children such as inhalational, intravenous, intramuscular, intranasal, oral, and less common today rectal administration of anesthetics (Motoyama, Gronert, and Fine, 2006). The anesthesiologist's choice depends on many factors, including the age of the child and underlying illness, the surgical procedure, as well as provider's skill and personal preference. Methods of induction also vary among institutions, for instance the use of an oral sedative premedication and inhalational induction is the most commonly used technique in pediatric anesthesia in the United States (Motoyama, Gronert, and Fine, 2006). However, at BC Children's Hospital the use of TIVA without anxiolytic premedication, is common practice and its approach is somewhat unique. This section will mainly focus on inhalational and intravenous induction of general anesthesia. Descriptions of induction methods refer to the book section "Induction of Anesthesia and Maintenance of the Airway in Infants and Children" (Motoyama, Gronert, and Fine, 2006) in "Smith's Anesthesia for Infants and Children". If applicable, details gained from attending anesthesiologists are added to further illustrate practice at BC Children's Hospital (BCCH).

1.2.2.1 Preanesthetic preparation and common principles Induction of anesthesia is considered the most stressful time period of general anesthesia for both pediatric patient and the anesthesiologist. Whether the patient will undergo inhalational or intravenous induction, there are common principles to minimize the emotional stress of anesthesia and surgery. To facilitate coping, child life programs have become standard in most pediatric centers. These programs address the psychosocial needs of pediatric patients during hospitalization and health care interventions, by using play, age-appropriate communication, and psychological preparation, perioperatively (Child Life Council and Committee on Hospital Care, 2006).
In a preoperative visit, the anesthesiologist meets the patient at eye to eye level and tries to find a line of communication through a toy, pet, favourite television show etc. It is important to quickly establish a relationship preoperatively in order to facilitate the least traumatic experience. The anesthesiologist gets an impression of what strategy is likely going to work with this particular patient during induction. Also, parental presence at induction of anesthesia (PPIA) can be discussed with the parents, and the need for preoperative sedatives evaluated.
When transferred to the operating room (OR), the patient is allowed to keep an object of choice (toy, stuffed animal, etc.) to provide security and emotional support. In the OR it is important that induction is smooth and uninterrupted by last-minute preparation of equipment as the patient may be afraid of strange OR environment, devices and staff. The approach is always tailored to the individual patient.

1.2.2.2 Inhalational induction Inhalational induction can be achieved easily and rapidly in cooperative patients and is often considered less objectionable to most children since it avoids awake intravenous catheter placement. However, claustrophobia from the mask and the smell of the anesthetic vapor may cause objection. Even though many anesthesiologists believe inhalational induction is less emotionally traumatic, pediatric patients may become apprehensive and resist the application of the mask resulting in prolonged induction and emotional distress (Sánchez et al., 2013).
At first, an assistant helps positioning the patient on the operating table while the anesthesiologist takes over communication and constantly reassures the child that he or she is doing fine. The patient can either lie down on the operating table or sit up and lean against the anesthesiologist's chest or lap. If parental presence at induction of anesthesia (PPIA) is permitted, the parent can also support the patient by hugging, holding hands, reassuring with calming voice or having the patient sit on their lap. Other staff members that are not involved in the induction process usually remain quiet or leave the OR until induction of anesthesia is completed. To not upset the patient in this strange environment, most monitoring devices will be attached as soon as the patient is anesthetized. However, pulse oximetry is an important monitoring device to continuously monitor heart rate and oxygen saturation during the

induction. A blanket to cover up the equipment usually helps to divert the patient's attention. The mask should always be shown to the patient first before applying it to the face with the mask being disconnected from the anesthetic circuit. Depending on the age of the patient, the parent or an assistant can also try the mask first to alleviate the fear of younger children. Ideally, the mask has already been shown to the patient in the Anesthetic Care Unit (ACU), or the patient has played with the mask before induction during a Child Life intervention. For better acceptance, the patient has chosen his or her favourite fruit-scented lipstick preoperatively. The flavour is now applied to the mask to mask/reduce the smell of the anesthetic vapor. To put the mask into position the anesthesiologist can pretend to need help by asking the patient to hold the mask on the face by him/herself. Once the mask is safely applied over nose and mouth, it is connected to the anesthetic circuit and started with nitrous oxide (N_2O) and oxygen (O_2), which is one of many techniques. The patient may react to the smell of inhaled anesthetic. This can be reduced by having the patient breath through the mouth. During induction phase, the anesthesiologist talks to the patient to reduce anxiety and discourages him or her from activities by suggesting soporific themes. The patient's apprehension might increase with the feeling of dizziness and disorientation while going to sleep, also the feeling of helplessly floating off in space is associated with induction of anesthesia. To prevent these sensations while losing control, the anesthesiologist constantly reassures the child by gently touching him or her. It takes one to two minutes for the full effect of nitrous oxide. At its peak nystagmus appears and sevoflurane is added to the anesthetic circuit. The eyes usually close and respiration becomes slower and regular, deeper, then shallower and more rapid before the patient becomes still. Once no reaction to verbal stimulation is noticed and the eyelash reflex is gone, adequate monitoring is attached. Another common approach is the single-breath vital capacity technique, whereby loss of consciousness is achieved by getting the child to take one or two deep breaths to the full tidal volume with 8% sevoflurane. A major advantage of this technique is rapid loss of consciousness within 34 seconds (Agnor, Sikich, and Lerman, 1998). At the end of induction, the parent is escorted out of the OR.

1.2.2.3 Intravenous induction Major advantages of IV induction are rapid onset of action of intravenous anesthetics such as propofol and elimination of the mask along with the unpleasant odor of the vapor. This technique, however, requires the use of a cannula for intravenous catheter placement. Associated obstacles are challenges to locate a suitable peripheral vein in pediatric patients as well as the child's fear of needles and the pain associated with it. Thus, the approach of IV induction is different to inhalational induction in many ways: During IV induction, the aim is to actively divert the patient's attention away from the needle, whereas the focus of inhalational induction is more on leading the patient to accept the mask.

Terminology: *Cannula* (also called *IV* or *IV cannula*) refers to the whole instrument (needle and catheter). The *catheter* describes the plastic tube that remains in the vein after withdrawal of the needle. An exemplary set-up of a cannula is shown in the Appendix, Fig. 23.

To alleviate, or ideally eliminate, the pain on IV insertion, topical creams such as EMLA, Ametop, or Lidocaine have been developed to provide dermal analgesia. The cream is placed on a promising peripheral vein about 30 minutes to one hour prior to IV insertion (the time to ensure full effectiveness depends on the individual cream) and covered by an occlusive band-aid. Potential sites for vascular access (VA) are dorsum of the hand which is usually the first choice of the anesthesiologist (see Fig. 2), the medial aspect of the ankle (saphenous vein), the lateral aspect of the foot, a scalp vein in infants, and the lateral aspect of the wrist in older pediatric patients (Lerman, Coté, and Steward, 2016c). However, the latter is hard to puncture and difficult to maintain in an awake child due to the high mobility of the wrist. Additionally, vein puncture at the lateral wrist is considered very painful. To optimize conditions, analgesic cream is often placed on two potential sites, for instance on the dorsum of both hands. On the downside, vasoconstriction is a problem associated with analgesic cream making IV insertion harder to achieve. The cream is usually taken off ten to fifteen minutes prior to induction; also warming the site can help widening the blood vessels and increases the visibility of the targeted vein (Lenhardt et al., 2002). Smaller hands and subcutaneous fat layers in younger patients, hence less visible veins, may also impede IV access.

When the patient enters the OR, the OR team assesses the patient's behaviour (cooperative, alert, anxious, resistant). This determines the approach to proceed. After a short introductory team talk (patient's name, age, weight, and type of surgery) the assistant helps positioning the patient on the operating table. Some basic monitoring devices, such as a pulse oxymeter, are attached to the patient prior to induction, since vital signs can vary markedly during induction. The anesthesiologist talks to the patient by referring to something the patient likes. This could be a stuffed animal or toy that the patient has chosen to bring with him/her, or a favourite TV show that is already playing on a screen inside the OR. There are many different distraction techniques that are used in diverting the patient's attention away from the needle, such as verbal distraction, screens (TV, iPad, Virtual Reality (VR)), books, etc. The method of choice depends on the age of the patient, the patient's interests and the preference of the anesthesiologist. Depending on the age of the patient, a hug from the parent while being distracted may also be beneficial for the patient in this strange OR environment. Due to the hug, the patient's hand is positioned behind the parent's back; thus the patient's view of the insertion site is blocked by the parent. This prevents frightening and may facilitate distraction during IV cannulation. Once the patient's attention is captured, the anesthesiologist removes the analgesic cream if still applied, has a look at potential veins and selects a suitable vessel. The venous network of the dorsal hand is the default venous access site at BCCH (see Fig. 2).

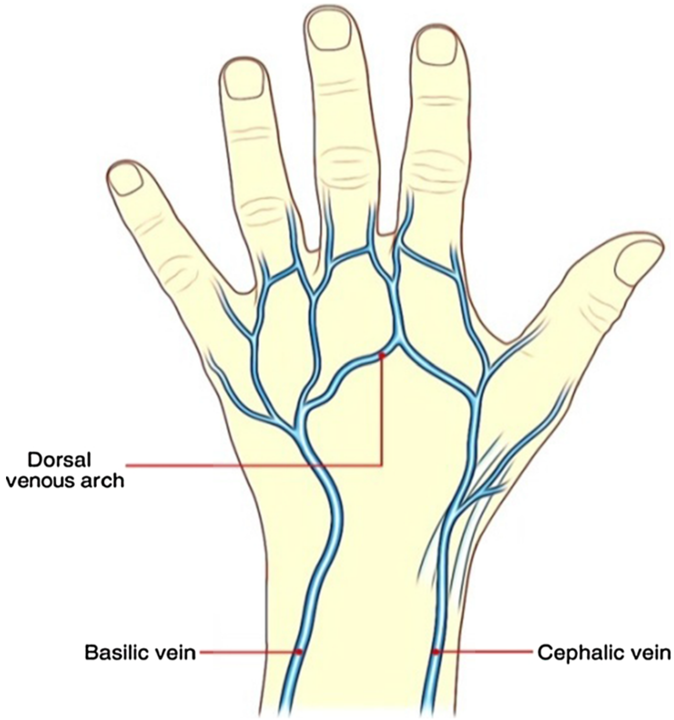

FIG. 2. Dorsal venous network of the hand
https://link.springer.com/article/10.1007/s00500-019-03991-8

A tourniquet is applied to the chosen extremity (dorsum of the hand as a default), which is then gently but firmly immobilized by an assistant to avoid sudden movements, while the anesthesiologist wipes the induction site with alcohol. Usually, the cannula is hold out of sight at all times or kept covered to prevent the patient from frightening; the OR staff may also avoid using the word *needle*. Once the alcohol is dried off, the anesthesiologist stretches the skin to fixate the vein and slides the safety IV cannula (compare Fig. 3) with bevel facing up through the skin into the vein (Lerman, Coté, and Steward, 2016c). The first flashback indicates, that the needle tip has penetrated the vein, but not the catheter. Then the bevel is turned down to avoid going through the distal wall of the vein, and the angle of approach is decreased, before advancing the catheter forward off the needle so that both needle tip and catheter are now in the vein. A second flashback of blood occurs between the catheter and the needle, confirming that the catheter is in the vein as well. Once the catheter is advanced completely, the anesthesiologist withdraws the needle from the catheter and makes sure that fluid can flow freely through the catheter without causing subcutaneous infusion.

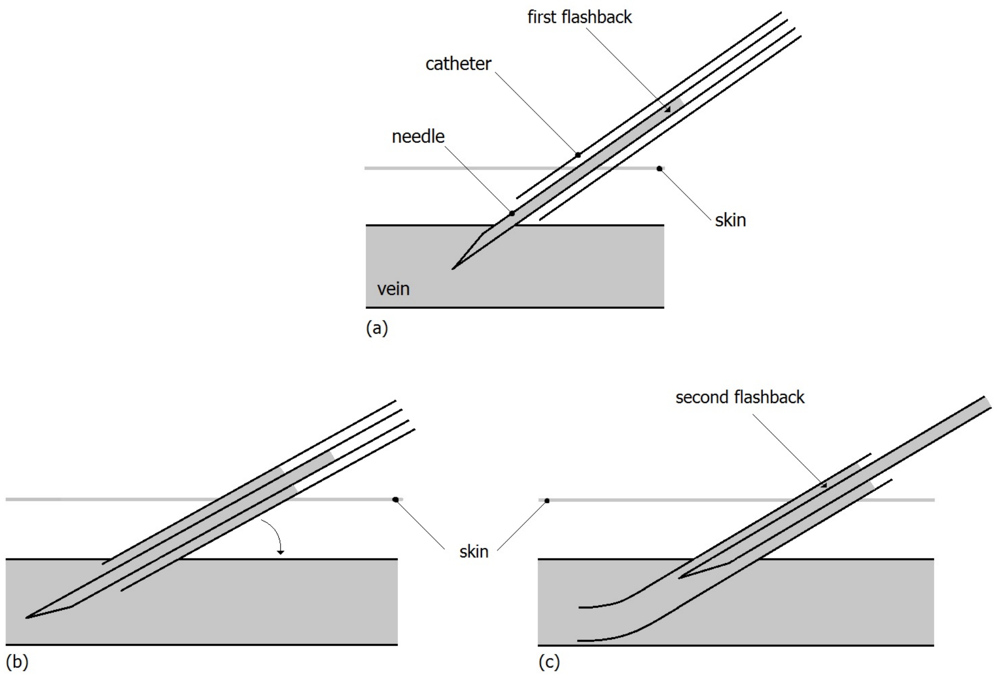

FIG. 3. Practical approach of venous cannulation; (a) needle in vein, catheter outside vein – first flashback only; (b) needle in vein, catheter in vein – first and second flashback; (c) successfully withdrawing needle and advancing catheter inside vein
(Harty, 2011)

The catheter is then covered with a sterile dressing and taped in place. The sterile dressing is usually appropriately themed for pediatric patients to prevent frightening. It is important to note, that insertion techniques vary among anesthesiologists and often individual approaches are developed over years of practice. Some anesthesiologists also give a little warning before inserting the cannula (*"you might feel a little pinch"*) or command (*"take a deep breath"*), depending on how involved the patient is with the ongoing distraction. Ideally, the patient has not felt the venipuncture due to successful dermal analgesia. The patient is now reassured by the OR team and parent and may be shown the colourful sterile dressing of the intravenous catheter depending on the level of distress. For injection of anesthetics, the patient can now choose to stay seated and being hold by the parent, or lay down on the operating table. If the patient is very upset by the previous procedure already, the anesthesiologist may decide to give anesthetics intravenously right away to avoid additional distress. The anesthesiologist administers a bolus of 3-5 $mg \cdot kg^{-1}$ of propofol in combination with lidocaine through the intravenous line and loss of consciousness occurs within 30 - 60 seconds (Lauder, 2015). An oxygen mask and additional monitors are applied immediately once the patient is anesthetized and the parent is escorted out of the OR.

1.2.3 Advantages and disadvantages of TIVA

In recent years, TIVA has gained popularity due to its many potential advantages over inhalational anesthesia (Lauder, 2015). Exemplary advantages and disadvantages of this technique are described below. A distinction is made between clinical, practical, and other advantages/disadvantages (see Appendix Tab. 2).

Advantages of TIVA

Clinical advantages of TIVA include reduced postoperative nausea and vomiting (PONV), reduced airway reactivity, reduced emergency delirium (ED), neuroprotection, and improved outcome in cancer surgery, among others.

- Postoperative nausea and vomiting: Propofol is known to have antiemetic properties, which reduce the occurrence of PONV. Since PONV can cause dehydration, wound dehiscence, or delayed recovery, TIVA is beneficial for children with a history of severe PONV, or surgeries with a high risk of PONV (Lauder, 2015; Shaikh et al., 2016).

- Airway complications: Propofol decreases airway reactivity, thus it is less likely to experience perioperative respiratory adverse events, such as laryngospasm or bronchospasm. Decreased airway reactivity further facilitates intubation and extubation. Therefore, TIVA is the method of choice for patients with increased airway responsiveness or shared airway procedures (Lauder, 2015; Gaynor and Ansermino, 2016; Ramgolam et al., 2018).

- Emergence delirium: A lower incidence of emergence delirium is associated with TIVA in patients aged 2 to 6 years. ED is a behavioural disturbance occurring at emergence from anesthesia; it can cause maladaptive behaviour development and lasting memory impairment (Chandler et al., 2013).

- Neuroprotection: There is evidence, that propofol may exert some neuroprotective effects on the developing brain. Thus, the use of propofol may be beneficial in neurosurgical procedures (Lauder, 2015).

- Oncology: There is growing evidence, that TIVA improves the overall survival rate of adult cancer patients, reduces cancer recurrence, and reduces the incidence of postoperative metastasis compared to inhalational anesthesia (Soltanizadeh, Degett, and Gögenur, 2017; Wu et al., 2018).

From a practical point of view, TIVA is readily titratable allowing for spontaneous ventilation (SV) to be maintained. There is no risk of exposure of OR staff to volatile anesthetics. Interference with sensory evoked potentials is minimal, resulting in TIVA as the choice of anesthesia for corrective spinal surgery. Sensory evoked potentials reflect the electrical activity of neural structures. They are measured to show differences in cortical activity during spine manipulation interventions, and to prevent or minimize neurologic morbidity caused by the intervention (Bithal, 2014; Passmore, Murphy, and Lee, 2014). Next, TIVA does not require an anesthetic machine and is easily transportable. This enables out of the OR procedures, such as in Magnetic Resonance Imaging (MRI), oncology, or burn dressing suites, which conversely make room for more major procedures in the ORs. A quick and good quality recovery further allows for decreased turnover times (the time from when the patient leaves the OR to the beginning of the induction process of the next patient), hence increased turnover of cases (higher frequency of procedures in the OR) (Lauder, 2015; Gaynor and Ansermino, 2016).

Other advantages include the avoidance of the seizure potential associated with sevoflurane anesthesia, and lower cost of maintenance of propofol TIVA compared to sevoflurane or desflurane. Cost saving due to reduced unplanned admissions

(PONV), quick recovery and improved discharge times, etc. can also be taken into account. TIVA further avoids atmospheric pollution (Lauder, 2015).

Disadvantages of TIVA
Clinical disadvantages are pain on IV cannulation, pain on propofol injection, the risk of infection due to bacterial contamination, and the risk of propofol-related infusion syndrome (PRIS), among others.

- Pain on IV cannulation: This is a major issue of TIVA. To ease the pain on venipuncture topical anesthetic creams have been developed and shown to be effective (Bond et al., 2016).
- Pain on propofol injection: Pain on injection of propofol remains a problem. However, co-administering lidocaine, pre-treating with opioids, using larger veins, or low initial infusion rates, among others, minimize the discomfort (Desousa, 2016; Lauder, 2015).
- Bacterial contamination: Propofol is insoluble in water and is therefore suspended in a lipid emulsion of soybean oil and egg lecithin. Consequently, bacterial contamination may occur and the risk of bacteria development increases with time (Lerman, Coté, and Steward, 2016b).
- Propfol-related infusion syndrome: The risk of PRIS increases with high propofol infusion rates or a prolonged infusion period (>48 h). PRIS implicates bradycardia and severe metabolic acidosis (Lerman, Coté, and Steward, 2016b).

Practical disadvantages include the requirement for IV access. Identification of suitable peripheral vein access can be difficult in young pediatric patients with subcutaneous fat on vein access sites, or obese patients (Nafiu et al., 2010). For intravenous anesthesia, there is no reliable electroencephalography (EEG) monitoring available for depth of anesthesia measurement. The risk of interstitial or disconnected IV access is another practical disadvantage of TIVA (Lauder, 2015). Other than with inhaled anesthetics (measurement of end-tidal gases), there is no measurement for the uptake of intravenous anesthetics during the procedure. Consequently, there is a risk that an interstitial or disconnected IV remains undetected until the patient moves.

Other disadvantages are the environmental impact of plastic waste (syringe and tubing) caused by TIVA and waste of unused propofol. Disposables may also be costly (Gaynor and Ansermino, 2016; Lauder, 2015).

1.2.4 Pharmacology of TIVA

At BCCH, propofol in combination with remifentanil is predominately used for induction and maintenance of anesthesia via the intravenous route. There are many other anesthetic agents and adjuvants used in pediatric anesthesia, such as sufentanil and dexmedetomidine, respectively. However they are beyond the scope of this work; further information is provided in the book "Manual of Pediatric Anesthesia" (Lerman, Coté, and Steward, 2016b).

Propofol
Propofol is a short-acting general anesthetic, which is used for induction and/or

maintenance of anesthesia. Propofol has sedative, amnestic, and some muscle relaxant properties. It does not provide analgesia and is therefore combined with an opioid (e.g. remifentanil) or ketamine, if analgesia is required (Tobias and Leder, 2011). The pharmacokinetics of propofol are well described throughout the age range of pediatric patients. Its benefits, among others, are rapid onset (consciousness occurs within 30 - 60 seconds after bolus of 3-5 $mg \cdot kg^{-1}$) and rapid emergence from general anesthesia, pleasant recovery, and less nausea and vomiting postoperatively compared to inhalational anesthesia (Lauder, 2015; Lerman, Coté, and Steward, 2016b). At induction, propofol causes a decrease in blood pressure and heart rate, along with depressed airway reflexes. As shown in Chapter 1.2.1.2 (Differences in response to pharmacologic agents), infants older than one year require the highest propofol induction and maintenance doses due to a larger central compartment and volume distribution, as well as a greater rate of clearance compared to older children and adults. Propofol is cautiously used in neonates due to the risk of severe hypotension. The use of propofol is not recommended for prolonged sedation within the entire pediatric population since it increases the risk of PRIS (Lerman, Coté, and Steward, 2016b).
Like other anesthetics, propofol has synergistic properties when administered with adjuvant agents, such as remifentanil. Drug synergism means, that the effect of two concurrently used drugs is enhanced compared to the response of each individual drug. This effect is dose-dependent (McCormack, 2007; Tallarida, 2001).

Remifentanil
Remifentanil is an ultra-short acting synthetic and potent opioid, used to provide analgesia during induction and maintenance of general anesthesia (McCormack, 2007; Gaynor and Ansermino, 2016). It is administered through the intravenous route as an adjunct to propofol (Lerman, Coté, and Steward, 2016b). The combination of the two drugs results in reduced propofol requirements and an increased respiratory depression once a certain rate is exceeded. However, higher doses are tolerated by pediatric patients compared to adults, while still maintaining SV (Gaynor and Ansermino, 2016). The elimination half-life of remifentanil (time required for the plasma concentration to decrease by 50%) is shorter in neonates and infants under the age of four months compared to adults. This is unique and beneficial in situations where a brief but intense effect is needed. Possible side effects include hypotension, apnea, bradycardia, and vomiting, among others (Lerman, Coté, and Steward, 2016b). It is recommended to administer remifentanil and propofol in separate syringes, since they undergo separation and layering in the same syringe, thus concentration of the components varies (O'Connor et al., 2016).

1.3 BCCH practice and induction bundle

The anesthetic department of BC Children's Hospital converted from inhalational anesthesia to predominantly TIVA over 20 years ago. Even though TIVA has become increasingly popular in recent years, performing IV inductions as a general institutional policy is not yet common. At BCCH, TIVA is conduced predominantly without anxiolytic premedication. A bundle of factors, not all of which have been identified yet, facilitates IV induction without sedative premedication. This might include:

- Parental presence in the operating room
- Age-appropriate distraction

- Cultural expectation and framing
- Buy-in by the entire health care team
- Analgesic cream placement on both hands
- Education

1.4 Motivation

Despite TIVA being the predominant technique used in the operating rooms of BC Children's Hospital, no documentation of the success rate of the IV induction bundle of care exists. Studies have demonstrated a first attempt success rate for peripheral venous catheter placement varying from 40.7 % to 72.0 % using the traditional visualization/palpation method (Demir and Inal, 2017; Inal and Demir, 2018; Goff et al., 2013; Basadonna, 2016). Results regarding vein visualization devices, designed to improve IV cannulation success rates, vary, whereby some studies report a positive influence on efficacy, whereas others show no difference (Szmuk et al., 2013; Van Der Woude et al., 2013). Since there is no comparable literature, quantifying the efficacy of intravenous induction of general anesthesia using the BC Children's Hospital bundle is extremely valuable information, as it will allow other centers considering such an approach to estimate their expected success rates. Additionally, the study results will show what performance is achievable and may provide evidence, that TIVA as a general institutional policy can be conducted without causing significant distress to pediatric patients.

1.5 Aim

This study aimed to identify the BCCH success rate of performing intravenous cannulation, defined as placement of an IV in ≤ 2 attempts. As a secondary outcome, key facilitators used by anesthesiologists to ensure success of the IV placement were documented. This will establish a baseline for other institutions considering to implement such an approach, and also to document internally the BCCH success rates and opportunities for improvement.

2 Methods

A mixed methods approach was chosen to collect and analyze quantitative OR data and qualitative semi-structured interview data (Tariq and Woodman, 2013). The study design, study procedures, and analysis will be explained in the following subsections.

2.1 Study Design

This prospective observational study of IV cannulation success for induction of anesthesia was conducted with University of British Columbia / Children's and Women's Research Ethics Board (UBC C&W REB) approval (H18-02649, 2018-12-4, PI: Eleanor Reimer). Written informed consent was obtained of staff pediatric anesthesiologists for their participation in the study; a waiver of consent was granted for patients and parents. Procedural suite nurses were eligible to participate in the interview part, for which they provided written informed consent.

The study was classified as observational study, to be more specific as prospective cohort study. Prospective means, that data were gathered along with study realization (from present to future), whereas retrospective studies look at data that has already been collected in the past. A cohort study is a primary type of observational study, that assesses causality between exposure to certain risk factors and outcome in a study population. Cohort studies always require a second comparative group serving as a control (Song and Chung, 2010).

The first part of the study (Part A), a prospective audit, was conducted over a one month period at regular OR capacity from 2018-12-10 to 2019-01-20, interrupted by two weeks end-of-the-year period. There were no elective procedures scheduled during the end-of-the-year slowdown. However, emergency cases occurring within this time frame were still included in the data collection. All patients undergoing general anesthesia in the entire procedure suites and Magnetic Resonance Imaging (MRI) at BCCH were included. Exclusions applied to procedures that were performed outside the main ORs, such as in oncology and burn dressing suites.

As a follow-up, semi-structured one-to-one interviews with selected anesthesiologists and interested procedural suite nurses were conducted (Part B). This was performed from commencement of OR data collection on 2019-01-15 until 2019-02-28.

2.2 Study Procedures

Study procedures describe methods and tasks to be completed from project start until the end of data collection. The study was conducted in three phases: Planning and Preparation, Enrollment and Consenting, and Clinical Procedures.

2.2.1 Planning and Preparation

During the planning phase preparations for ethical review by the UBC C&W REB were made. This involved drafting protocol and consent forms, as well as data collection tool set-up in Research Electronic Data Capture (REDCap) (Harris et al., 2009).

Protocol

The protocol can be considered as a guideline of the study and allows the researcher to plan and review the study's progress throughout the realization phase. Writing and submitting a protocol to the UBC C&W REB for review is required by the Tri-Council Policy Statement 2 (TCPS2) in order to achieve approval of the proposed study (Canadian Institutes of Health Research, Natural Sciences and Engineering Research Council of Canada, and Social Sciences and Humanities Research Council of Canada, 2014).

Participant Information and Consent Form

A 'Participant Information and Consent Form' guide and template was provided by the University of British Columbia (UBC), which was adjusted to the individual study design of the IV induction audit. The consent form was also submitted to UBC C&W REB for review and approval.

A consent form signed by the participant is a common method of documenting the consent discussion and agreement to participate in a research study. A consent form must provide all information that is required to make a free, informed and ongoing decision by the participant (Canadian Institutes of Health Research, Natural Sciences and Engineering Research Council of Canada, and Social Sciences and Humanities Research Council of Canada, 2014). Among other things, the consent form informs participants about the study background, who is conducting the study, what the study involves, the participant's responsibility, confidentiality, as well as possible risks, harms, discomforts, and benefits of the participation (The University of British Columbia, 2015). For the IV induction audit, attending pediatric anesthesiologists and procedure suite nurses were invited to take part in the research study. After discussion of the study and allowing for deliberation by the participant, consent forms were signed by both participant and researcher.

Data Collection Form

The first version of the data collection form was drafted by the study coordinator (AP) leveraging his expertise and experience with clinical research. The data collection form was also submitted to the UBC C&W REB for approval, both initially and after subsequent modification. The data collection form was designed with the goal of fitting all fields to be completed on a single page, and presenting them in logical order. The form captured patient demographics, planning variables, information on the environment during IV attempt(s), and information on the IV placement (compare Appendix Fig. 24).

Most information was provided by selecting from multiple choice lists with either multiple options or mutually exclusive options. Only little information, such as number of IV insertion attempts or times had to be provided manually by anesthesiologists, thus the form could be completed with minimal effort and also quickly. It is important to note, that no patient identifying information was documented.

During the first week of data collection in the ORs, 51 % of returned data collection forms were partially incomplete. This resulted in the design of the data collection form from being modified from a visual approach (compare Appendix Fig. 25) to a consecutively numbered, logical approach (compare Appendix Fig. 24). Additionally, often missed fields (time topical applied, time of first IV attempt) were highlighted and the field 'vascular access in place?' was included to the second version of the form. Completeness of data collection forms continuously improved over collection period.

Research Electronic Data Capture System

REDCap is a research data collection tool created and maintained by Vanderbilt University since 2004. In a highly secured web application researchers can capture sensitive information effectively and responsibly, build and manage online surveys, and create databases and projects (Harris et al., 2009). The collected data can be exported directly to common statistical programs (SPSS, R, etc.) and other data software for further analysis. Additional advantages are improvement of consistency and accuracy of entered data through validations, improvement accessibility (web-based access on and off site, with multiple user rights), and it enables flexible design that allows modifications at any time.

At BC Children's Hospital Research Institute (BCCHR), researchers are encouraged to store and manage data in REDCap for all research studies involving clinical data collection. Therefore, a data collection instrument was set up for the IV induction audit with similar design to the data collection forms for easy data entry. For each research question, a field was created in the REDCap tool and following characteristics were defined (see Fig. 4):

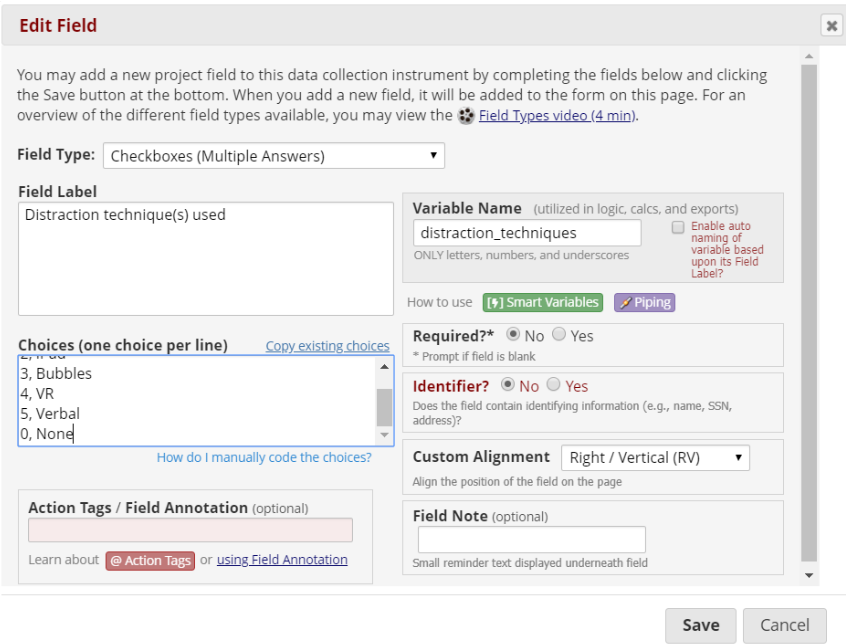

FIG. 4. REDCap Online Designer: field set-up

- Field Type: There are twelve different field types to choose from. The type of field depends on the question: Checkboxes were used when multiple answers could be given, radio buttons or drop-down lists for single answer questions, and text boxes for short texts or numbers. Also, yes-no fields were used for some questions.

- Field Label: The field label is usually either a question, such as 'Parent/Guardian present?', or a standard label, such as 'Age:'.

- Answer Choices: These are specifically for multiple choice field types (checkboxes, radio buttons or drop down lists). Here, the answer options are listed and automatically coded with numbers for storage and data analysis purposes.

- Variable Name: REDCap uses the variable name internally to store the data. It is recommended to keep variable names short but descriptive, so that it is possible to recognize variables when analyzing the data.
- 'Required' Option: Its default setting is 'No'. If changed to 'Yes' an answer must be provided to the question in order to save the record. For this study, mostly variables in the section 'Patient Demographics' were required fields.

Besides designing the data collection tool, additional functions such as branching logic can be applied. Branching logic is used, when a field (or group of field) should only be displayed conditionally based on the previous field (e.g. 'IV induction successful?', if yes 'Provider on successful attempt:'). At last, the data collection instrument was tested and reviewed by BCCHR before moving it into Production Mode. Once it has been approved and moved to Production Mode, data collection can be conducted. When creating new records, they are automatically numbered sequentially by REDCap. Each record has a unique record number that serves as an identifier in data analysis. During the data collection period, preliminary results can be monitored with the Report Builder. By applying filters, specific groups can be identified or certain demographics of the study population revealed. Reports were also useful in observing the completeness of returned data collection forms during the collection period.

Interview Questionnaire
The questionnaire guide for conducting semi-structured interviews was also designed in REDCap during the planning phase. It was then submitted to the UBC C&W REB for review and approval together with the protocol. Besides a Record ID and room for additional comments the following four questions were asked:

1. Which factors do you think contribute to a successful IV attempt?
2. Which factors do you feel pose barriers to a successful IV attempt?
3. What are the top three distraction techniques you think work best? Options are: TV, iPad, Bubbles, VR, Verbal, and Other.
4. What advice would you give a new resident before their very first IV attempt?

Semi-structured interview questions are more open-ended and allow for discussion of answers. Follow-up questions could be asked based on the response of the participant to emphasize and further explore specific points.

UBC C&W REB Approval
Research Ethics Boards (REBs) are independent committees who review the ethical acceptability of research involving humans. Research Ethics Boards (REBs) operate independently in their decision-making and are free of inappropriate influence on behalf of a hospital or a research institute to protect the welfare of study participants and ensure that international, national, and institutional ethical requirements are met (Provincial Health Services Authority, 2019; UBC C&W Research Ethics Board, 2014). When submitting an application for ethical review, the REB can either approve, reject, propose modifications to, suspend, or terminate any proposed research (Provincial Health Services Authority, 2019). Once the application is submitted, no changes may be made until researchers receive a response by the REB.

The IV induction audit was considered a minimal risk study and could therefore undergo a Delegated Review, which was conducted by a single REB reviewer (Provincial Health Services Authority, 2019). No deadlines were applied in this case since a meeting of the full UBC C&W REB, which meets monthly, was not required. According to TCPS2 (compare page 32, TCPS2), minimal risk applied because "the probability and magnitude of possible harms implied by participation in the research is no greater than those encountered by participants in those aspects of their everyday life that relate to the research". Patients and parents were not approached in accordance with TCPS2, Section 3.7.

2.2.2 Enrollment and Consenting

Once the research study was approved by the UBC C&W REB, written informed consent from every staff pediatric anesthesiologist at BCCH was obtained for Part A (a total of 28 anesthesiologists). Participants were ensured their participation was kept confidential. Participants were also entitled to withdraw from the study at any time without giving reasons. As previously described, patients and parents were not approached for this study in accordance with TCPS2, section 3.7.

Consenting of interested procedural suite nurses for semi-structured interviews was conducted during the data collection period in the ORs. A total of eleven anesthesiologists and two procedural suite nurses participated in Part B.

2.2.3 Clinical Procedures

A stack of printed data collection forms were stored in labelled collection envelopes. The collection envelopes were then attached to the side of the anesthesia machines inside the 13 ORs and two MRI suites for easy access by the anesthesiologists. For each induction of anesthesia, the attending anesthesiologist documented information regarding patient demographics, planning and environmental details as well as information about the IV placement. The completed form was then placed back into the envelope and collected on the same day.

Collecting the forms daily enhanced completeness of data for two reasons. First of all, the patient's chart was not yet transferred to its long-term storage location but was still accessible if needed for data verification. Incomplete patient demographic data could therefore be added by a researcher after the procedure. Second of all, cases were still fresh in the memory of attending anesthesiologists on the day of the procedure and discrepancies in the data collection forms were easy to correct. The forms were collected by a researcher and data were entered into REDCap. After data entry, the forms were securely stored and locked and will be securely shredded after their mandatory 5-year storage period has expired.

Interviews were conducted once data collection in the ORs was completed. Procedural suite nurses were interviewed to provide information from a different perspective. Interviews with both anesthesiologists and procedural suite nurses were stopped once saturation has been reached, whereby no new findings/results became available. The interviews were conducted in a private setting, allowing participants to freely express their opinions. The interviews were audio-recorded and transcribed in Microsoft Word, after which the audio-records were deleted.

2.3 Analysis

For analysis of collected data, different approaches were used based on the type of data. Quantitative data collected in the ORs were analyzed in MATLAB (The Mathworks Inc, Natick, MA) by applying various statistical test, such as Fisher's Exact Test, Chi-Square Test, Mann-Whitney-Wilcoxon Test, and Logistic Regression. A P-value of <0.05 was deemed statistically significant for all comparisons. Qualitative analysis of semi-structured interview data were performed in NVivo 12 Pro (QSR International Pty Ltd, Melbourne, VIC).

2.3.1 Sample Size and Sampling Method

For prospective data collection in the ORs, convenience sampling over a one month data collection period was conducted, resulting in an estimated sample size of 1000 cases. This theoretically allowed capturing at least 25 cases for each anesthesiologist and would enabling de-identified comparison between peers.
During the one month data collection period, a total of 990 cases were captured (compare Fig. 5). Six cases got excluded due to missing information on patient age or success/failure of the IV placement, resulting in 984 cases available for analysis. Case capturing was conducted by comparison with OR slates during the prospective data collection period. Once OR data collection was completed, the overall number of assigned cases was verified by the internal data base of case assignments.

For qualitative research interviews, a semi-structured interview approach was chosen to gather textual data. The purpose of semi-structured interviews is to investigate the interviewee's perspective and experience on the research topic (McIntosh and Morse, 2015; King, 2004). Semi-structured interviews use mostly open-ended questions that induce descriptive, lengthy answers and allow new ideas to be brought up during the interview as a result of the interviewee's answer (McIntosh and Morse, 2015). Also, the interview was not constrained to a particular format and follow-up questions could be tailored to the individual interviewee while still following a well-prepared questionnaire guide. This enhanced the understanding how and why a particular perspective was obtained by an interviewee.
A total of 5-10 anesthesiologists and 5-10 procedural suite nurses were tageted for participation. Anesthesiologists were recruited by the researcher according to their individual practice of induction methods, which was observed and analyzed during OR data collection. The goal was to reflect a representative spectrum of induction practice among participating anesthesiologists. Therefore, anesthesiologists from both the "inhalational (IH) end" of practice spectrum (higher-than-average number of IH inductions) and the "TIVA end" of practice spectrum (higher-than-average number of IV inductions) were interviewed, as well as anesthesiologists without a distinct preference to one or the other induction method. Procedural suite nurses were approached and consented based on their interest in participating in the study. Once saturation was reached or no new information became available, interviews were stopped. Due to a diversity of interviewees, the research topic could be seen from different perspectives and a range of opinions on IV induction could be shown.

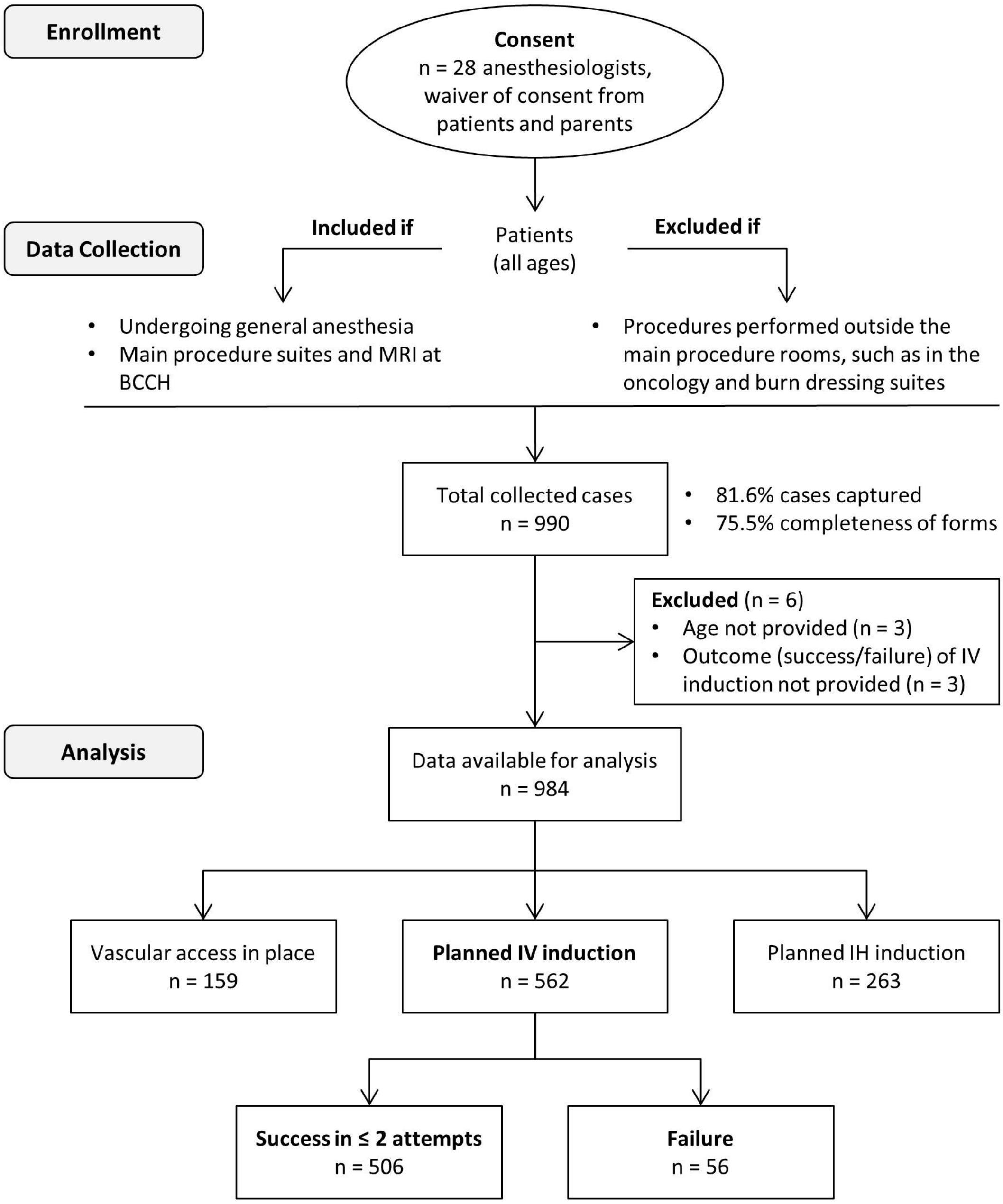

FIG. 5. OR data collection: Inclusion/exclusion criteria and group assignment of the overall study population available for analysis

2.3.2 Outcome Measures

Primary outcome was the success of the IV placement at BCCH. Success was determined by a successful IV cannulation in ≤ 2 attempts. Secondary outcomes were:

- Number of attempts
- Whether an anxiolytic was given
- Time topical anesthetic was applied
- Reaction to skin- and vein puncture(s)
- Key factors and facilitators/barriers identified in BCCH IV induction bundle success

2.3.3 MATLAB Data Analysis

Analysis of Part A prospective outcome data was performed in MATLAB R2018b, a programming platform for engineers and scientists. It is a matrix-based language allowing its users to perform analysis and visualization of data, develop algorithms, and create models and applications, among other features (The MathWorks, 2019).

Preprocessing
Part A outcome data were exported from REDCap as CSV spreadsheet and imported to MATLAB for analysis. Before analysis of data could be conducted, data had to be preprocessed. Cases with missing information on outcome measures, such as success/failure of IV induction and age of the patient, were excluded (see Fig. 5). The variable 'patient age' was represented as a category and converted from a REDCap category label (numbers from 1 to 23, see Appendix Tab. 3, middle column) to an actual age in years and rounded to the second decimal for age categories less than one year (see Tab. 3, right column). For all patients, the middle value of each age step was used for calculations.

Defining groups
For analysis of prospective outcome, overall study population data available for analysis were divided into groups shown in Fig. 5. First, data of 984 patients were assigned to one of the three groups 'Vascular access in place', 'Planned IV induction', and 'Planned IH induction'. The 'Planned IV induction' group was further divided in possible outcomes of the IV induction (≤ 2 attempts implicate success, $>$ 2 attempts fail). It was assumed, that patients with VA in place underwent an IV induction. The 'VA in place' group and the 'Planned IV induction' group represent the proportion of planned TIVA practice at BCCH, which is different to the proportion of patients that actually underwent TIVA (represented by patients with VA in place and patients with successful IV placement). In other respects, the 'VA in place' group was excluded from secondary analysis since no additional IV placement for induction of anesthesia took place; hence no data has been collected for those patients. Also, it was assumed that unsuccessful cannulation attempts eventually resulted in IH induction (the thresholds of switching to IH induction may vary with providers). Groups that were included in the advanced data analysis are 'Planned IV induction' ('Success in ≤ 2 attempts', and 'Failure') and 'Planned IH induction'.These are referred to as *study population* for simplicity reasons, whereas the *overall study population* includes all groups available for analysis.

Overall success rate of BCCH IV induction bundle
At first, the overall success rate of the BCCH IV induction bundle was determined. All patients with planned IV induction served as denominator. As previously mentioned, success was defined as equal or less than two IV cannulation attempts. More than two attempts were considered as a failure of the BCCH IV induction bundle and patients were assigned to the 'Failure' group.
Subgroup analysis of the overall study population was conducted by age group and by attending anesthesiologist, to identify success rate variability by age and provider.

Analysis of study population demographics The following characteristics were analyzed within the study population: Median age, male/female ratio, proportion of autistic patients, and proportion of previously anesthetized patients. Outcome data

were presented in tables as fractions.
The variables 'anxiety documented' and 'anxiolytics given' were further analyzed. More specifically the distribution of given anxiolytics within the two populations (patients with/without documented anxiety). That for, both variables had to be given for analysis of documented anxiety and given anxiolytics. The type of anxiolytic drug uses was also analyzed. Results were presented in a flowchart and a bar chart.
The proportion of topical applied as well as which topical was applied was further investigated. In order to calculate the time frame of an applied topical, both variables 'Time topical applied' and 'Time of first IV attempt' must be provided on the data collection form, else cases were excluded from this particular analysis. Data were presented as histogram and bar graph.

Analysis of environmental and IV placement characteristics
Environmental and IV placement characteristics were analyzed within the 'Success in ≤ 2 attempts' and 'Failure' groups. This involved the following variables: child behaviour when encountered and immediately before IV insertion, parental presence, distraction technique(s), reaction(s) on skin- and vein puncture, pain on propofol injection, and provider on attempt(s). Due to incompleteness of data, individual patients were excluded from analysis for some variables, which is further specified in the following paragraphs if applied. Outcome data were presented in tables as fraction, flow charts, bar graphs, and boxplots for representation.

The variables 'Child's behaviour when encountered' and 'Child's behaviour immediately before IV insertion' were investigated for transitions between the behaviour categories calm, distressed but cooperative, and combative. The outcome was presented as flowcharts and bar graphs.

Multiple distraction techniques could be applied to one patient. However, exclusions applied to the 'no distraction' field, for which no other distraction technique was allowed to be checked. If 'no distraction' and another distraction technique, e.g. TV, was checked, the case was allocated to TV distraction.

The variables 'Reaction on skin puncture' and 'Reaction on vein puncture' provided data for up to two IV insertion attempts with three answer options, none, slight, and severe (compare Fig. 24). The category was determined based upon the child's reaction to skin -and vein puncture: 'none': the child may have noticed, but was not bothered; 'slight': facial grimace, withdrawal of hand; and 'severe': child cried, screamed, vigorous withdrawal of hand. When pooling attempts for an overall reaction, additional inclusion and exclusion criteria were applied, which are explained next. Patients with an unknown number of attempts were excluded from analysis.
The most stringent criteria were obeyed when allocating patients to the painless/no reaction category. Exclusions applied to patients with more than two IV insertion attempts because it is not possible to draw firm conclusions about reactions on any further attempt beyond documentation. For a successful IV placement with one or two attempts, reaction on both skin -and vein puncture must be given and defined 'none' on final attempt. Additionally, for patients with two attempts at least 'Reaction on skin puncture' must be provided at first attempt. Without these conditions being met, data were considered incomplete and the patient was excluded from reaction analysis. However, if IV placement was unsuccessful, missing 'Reaction on

vein puncture' was accepted at any attempt (vein may not have been hit) as long as 'Reaction on skin puncture' was provided though.
The categories slight reaction and severe reaction included patients with more than two IV placement attempts. Inclusion and exclusion criteria differed from the 'none' reaction category in that any recorded score was sufficient for category assignment. In doing so, an upgrade principle was applied: The worst of the given skin- and vein reaction(s) determined the category the patient was allocated to. For instance, a patient with two attempts of which one (or more) of the four scores was ranked 'slight' was allocated to the slight reaction category. If one (or more) of the four scores was ranked 'severe', the patient was allocated to the severe reaction category. This ensured the most conservative allocation of patients. Outcome data for all three categories were presented in tables as fractions and displayed in boxplots to show variability among anesthesiologists.

Fisher's Exact Test
The Fisher's Exact Test is a hypothesis test that performs well with smaller sample sizes and was used for analysis of categorical data (Glantz, 1992; Freeman and Campbell, 2007). Categorical data, other than measurable numerical data, is a type of data that can be grouped, such as gender. The test required data to be numbers (not percentages), and to be arranged in a 2 ×2 contingency table. Columns represented the two study groups, rows demonstrated the two outcome options. The null hypothesis H_0 of the Fisher's Exact Test states, that there is no association between the rows and columns of the table (Ramakrishna, 2005; Freeman and Campbell, 2007). In other words, the probability of a particular outcome (e.g. success in ≤ 2 attempts or failure) was not influenced by the study population (e.g. male/female). Details on conducting a Fisher's Exact Test manually can be found in the book "Primer of Biostatistics" by Stanton A. Glantz (3rd edition, 1992), among others.

There are one-sided (data is falling on one side of the distribution) or two-sided versions of the Fisher's Exact Test (data is falling on both sides) (Ramakrishna, 2005). Before analyzing the data, no assumption was made about values of one group being equal/greater or equal/less than values of the other group. Therefore, a two-sided Fisher's Exact Test was conducted which tested for a relationship in both directions. The test was used for comparisons of the following characteristics in the 'Success in ≤ 2 attempts' and 'Failure' groups: gender (male/female), autism (yes/no), anxiety (yes/no), anxiolytics given (yes/no), has previously been anesthetized (yes/no), and topical analgesic applied (yes/no). The MATLAB function *fishertest* was used with the additional parameters for a two-sided test and a significance level of p = 0.05 (probability of 5 %). MATLAB returned the result of the Fisher's Exact Test in the hypothesis variable H (H = 0 indicated that H_0 could not be rejected, H = 1 indicated rejection of H_0) with associated p-value. A p-value of less than 0.05 was deemed statistically significant, concluding that there is a statistically significant difference between the 'Success in ≤ 2 attempts' and 'Failure' groups.

Chi-Square Test
Both Fisher's Exact Test and Chi-Square Test were used for testing independence of categorical variables and significance of differences between proportions (Ramakrishna, 2005). Both test provide the same outcome (rejection of H_0 or acceptance of alternate hypothesis, p-value) in MATLAB, however, they are calculated differently. Main differences between the two tests are: The p-value of the Chi-Square Test is an

approximation whereas it is an exact calculation with the Fisher's Exact Test; also Chi-Square Test is very sensitive to sample size (cells should be five or more, if the frequency is less Chi-Square Test cannot be used) and proportions. Additionally, Chi-Square Test is not limited to a 2 ×2 contingency table but can be applied to a 2 ×3, 3 ×3, or even larger formats (Ramakrishna, 2005). This test was used to analyze the child's behaviour when encountered and immediately before IV insertion (study group with scores: 'calm', 'distressed but cooperative', 'combative') in association with the outcomes IV placement successful and IV placement unsuccessful. The MATLAB function *chi2cont* was used for the implementation of the Chi-Square Test.

Mann-Whitney-Wilcoxon Test

The Mann-Whitney-Wilcoxon (MWW) test, also known as Mann-Whitney U Test or Wilcoxon Rank Sum Test, can be used for nonparametric data (data does not fit a normal distribution) (Ramakrishna, 2005). Other requirements of the MWW are that two independent samples are drawn from the same population (e.g. 'Success in ≤ 2 attempts', and 'Failure') and that data can be ranked higher or lower, which applied to the variable 'Patient Age'. The MWW test can be performed one-sided or two-sided. H_0 assumes, that the independent samples are equal.
At first, ages were sorted based on their magnitude (from youngest to oldest age observed) in both samples. Next, the data were ranked in ascending order, rank 1 was assigned to the youngest age. If a certain age was represented several times, they were assigned the same rank by calculating the average of the tie ranks as if there had been no tie (e.g. they would have been rank 5 and rank 6, so both were assigned rank 5.5). Then, the rank sum in both samples was computed and the value of the sample with the fewer observations was assigned to T (Ramakrishna, 2005). Lastly, the critical value U was computed using T (see Form. 1) and evaluated through a Probability Distribution Table (ScienceDirect, 2019). Here, the associated p-value could be found which was used to decide whether or not to reject H_0. A two-sided MWW test was conducted for the variable 'Patient Age' in MATLAB using the *ranksum* function.

$$U = n_1 \cdot n_2 + \frac{n_1 \cdot (n_1 + 1)}{2} - T \tag{1}$$

Where:

$$\begin{aligned} U &= Critical\,value \\ n_1 &= Sample\,size\,of\,smaller\,sample \\ n_2 &= Sample\,size\,of\,larger\,sample \\ T &= Rank\,Sum\,of\,smaller\,sample \end{aligned}$$

Logistic Regression

Logistic regression is a mathematical approach to create a model that represents the relationship between various input variables and a binary outcome. Based on this model and the respective input variables, the probability for a particular event can be evaluated. The input variables are of categorical or continuous types, whereas the outcome probability is limited to a range between 0 and 1. This value can be interpreted as the probability of an event (Kleinbaum and Klein, 2002; Ramakrishna, 2005). The logistic function consists of a linear combination of the input variables, which are then converted to the limited outcome using the *logit* function.

For analysis of IV induction audit data, a logistic regression model was designed, including risk confounders age, sex, autism, known pre-existing anxiety, anxiolytics given, previously anesthetized, local anesthetic applied, child behaviour when encountered, and parental presence. Using logistic regression modeling in R (R Foundation for Statistical Computing, Vienna, Austria), the extent to which the variables were associated with success/fail of the IV placement was explored. The returned model provided the following information: odds ratio, 95 % confidence interval (CI), and p-value. Bi-directional Akaike information criterion (AIC) optimization was applied to reduce the regression model in R (Dziak et al., 2019). Both Logistic regression and AIC were computed in R since MATLAB did not provide the optimization feature for AIC.

2.3.4 NVivo Data Analysis

NVivo is a qualitative data analysis software for organizing, categorizing, analyzing, and visualizing non-numerical data, such as interviews, surveys, or field observations (QSR International Pty Ltd, 2019d). NVivo is used to examine and record relationships between the data and enables to find common topics and patterns. It further provides various chart and graph models to display those findings. Interview transcripts were managed in NVivo 12 Pro. Each participant was assigned a participant number P#. Analysis was conducted in four phases: organizing, coding, categorizing, and theme developing.

Organizing data
At first, a word frequency query including all transcripts was performed. Word frequency queries, as the name indicates, list most frequently occurring words within a source. This was useful in the early stages of the project to get an impression of what participants were saying and to identify possible themes. When applying a word frequency query, there are certain parameters to be set: number of displayed words, minimum length of words, and grouping. Grouping refers to the scope of words to be included, such as exact matches (e.g. talk), stemmed words (e.g. talking), synonyms (e.g. speak), specializations (e.g. whisper), or generalizations (e.g. communicate). Individual settings chosen for word frequency queries can be seen in Tab. 4. Results of the word frequency query applied to the overall transcripts were presented in a word cloud, which emphasized the frequency of words in different font sizes. The larger and bolder the word is displayed, the more a particular word was mentioned, however, colours are chosen randomly in word clouds. When conducting a word frequency query, NVivo ignores less significant words such as conjunctions or prepositions (‘and’ or ‘into’, respectively) (QSR International Pty Ltd, 2019c). Additional words that were not contributing to the result were manually excluded by adding them to the Stop Word List (see Appendix, Tab. 5). This was done iteratively throughout the processes.

In NVivo, words cannot be manually defined as synonyms. Synonyms in the context of the study were child/children, kid/kids, and patient/patients. NVivo analyzed those words individually, thus similarities and dissimilarities within the data were not recognized as they should have been. Therefore, the excerpt ’/child’ was added manually to any of the following words in the interview transcripts: children, kid, kids, patient or patients. Subsequently, the words children, kid, kids, patient, and patients were added to the Stop Word List.

Coding

Next, data were organized by coding, which is an essential part of qualitative data analysis. Coding means to gather and store relevant information on a particular topic, theme, person etc. in a container, called 'node'. The consistency of coding and nodes was crucial in order to see relationships between nodes. Nodes were organized based on the four questions asked in semi-structured interviews. Within each of the four nodes, additional specified nodes were created dynamically while investigating the interviews one by one (see Fig. 6).

Nodes

Name	Files	References
Other	4	7
Q1 - Factors contributing to IV success	0	0
Q2 - Factors posing barriers to IV success	0	0
Q3 - Distraction techniques	0	0
Age and development dependent	7	7
Bubbles	12	22
Child dependent	8	9
iPad	12	13
Other distraction techniques	7	8
Other Q3	6	8
Parental presence	4	7
TV	11	23
Verbal	12	25
VR	7	8
Q4 - Advice	0	0

FIG. 6. Nodes set-up: questions and subordinated grouping

When relevant information was identified, the respective excerpt was dragged and dropped into the corresponding node. If there was no such node for this specific theme yet, it was created before assigning excerpts. Information was not related to the research questions, excerpts were assigned to the 'Other'-node, which was excluded from analysis (see Fig. 6, first node). NVivo also provided both number of files (interviewees who had an opinion on a particular theme) and number of references (individual statements on a particular theme) that were included in the given node. The file number helped gaining first impressions about the range of certain themes among participants (questions headers such as 'Q3 - Distraction techniques' were left blank intentionally, any information was assigned to nodes listed underneath). For analysis purpose, multiple coding of an excerpt was mostly avoided, since it could affect word frequency queries and analysis of individual questions whereby relationships within duplicated excerpts would be emphasized.

Categorizing data

Interview questions were analyzed individually in order to identify broad categories. For all four questions, word frequency queries were performed. Queries help in exploring patterns and finding connections between themes by gathering material that has been coded in nodes. They can be conducted with combinations of nodes or by nodes with specific attribute values. The former query has been performed on each question, whereby all nodes assigned to the respective question were included in the query. Themes in Questions 1-4 emerged by using cluster analysis, which is an exploratory technique to visualize patterns within nodes. There are different cluster analysis diagrams to select from (cluster maps, dendrograms, and a circle graph), in this case circle graphs were chosen for visualizing findings and were clustered by word similarity. In a circle graph, most frequently used words are represented as points on the perimeter and may be connected with lines of various thickness and colour indicating if correlation (similarity) or contradiction (dissimilarity) exist between those items (QSR International Pty Ltd, 2019a). A blue line indicates correlation, whereas a red line indicates contradiction. The thicker the lines are the stronger the correlation or contradiction - depending on the colour. When creating the graph, only strong correlation were connected, however, this could be changed by adjusting the limits of the upper and lower similarity index value; consequently more or less lines were shown. NVivo calculated these similarity index values by comparing the occurrence and frequency of each different word within the text of nodes. If there were many equally strong correlations in the text, the similarity index in the circle graph was set to a high value (e.g. 0.9) in order to keep the circle graph clearly arranged (weaker correlations won't be shown). Based on the similarity index, NVivo grouped the items into clusters (ten by default), which could be distinguished due to the different colours of items. The number of clusters in the graph could be manually altered if needed. Also, the number of words included into the circle graph varied by question; words were added as long as new correlations, clusters, or knowledge on data became available by including another word into the query, and stopped once this was not given anymore. Circle graphs help in finding potential connections between items and developing themes. Individual settings of circle graphs for Questions 1-4 can be seen in Appendix, Tab. 4.

Data from Question 4 (first-IV advice to novices) were explored using a text search query, a tool to explore context surrounding a search word or phrase within the source material of Question 4 (QSR International Pty Ltd, 2019b). The amount of context (number of words) around a search word could be adjusted. The most frequently used words were used as search words.

Developing themes

Themes were generated from categorizing data and visualized in mind maps to address the four questions used in the semi-structured interviews. Mind maps demonstrate theoretical concept groups, how they are connected, and the hierarchy of obtained themes.

Quotes

Lastly, quotes were extracted to further illustrate the participant's perspectives on research questions. Quotes are referred to by using the participant code.

3 Results

The results of the IV induction audit are split into results of prospective OR data collection (Part A), and results gained from semi-structured interviews (Part B).

3.1 Part A: Prospective OR data collection

Data from 984 cases were available for analysis. The overall capture rate of assigned operating room cases was 81.6 % (990/1213). The overall number of procedures performed between 2018-12-10 and 2019-01-20 includes emergency cases, which might not have been reliably captured, and MRI patients, who may not have undergone general anesthesia.
Of cases, for which a case report form was completed, inhalational induction was planned for 263 cases (27 %), and vascular access was already in place for 159 cases (16 %). A total of 562 cases (57 %) with planned IV induction required peripheral vein cannulation for IV access.

3.1.1 Primary outcome

IV cannulation was successful in ≤ 2 attempts in 90 % (506/562) of cases, with a median [interquartile range (IQR)] of 1[1-1] attempts.

3.1.1.1 Success by age and provider Induction practice of attending anesthesiologists varied with patient age. The largest proportion of TIVA practice (patients with vascular access in place or successful IV induction) was seen in the age group of 17 years (93 %); the largest proportion of inhalational induction practice (patients with planned IH induction or failed IV induction) was observed in 1 year old patients (61 %) (see Fig. 7).

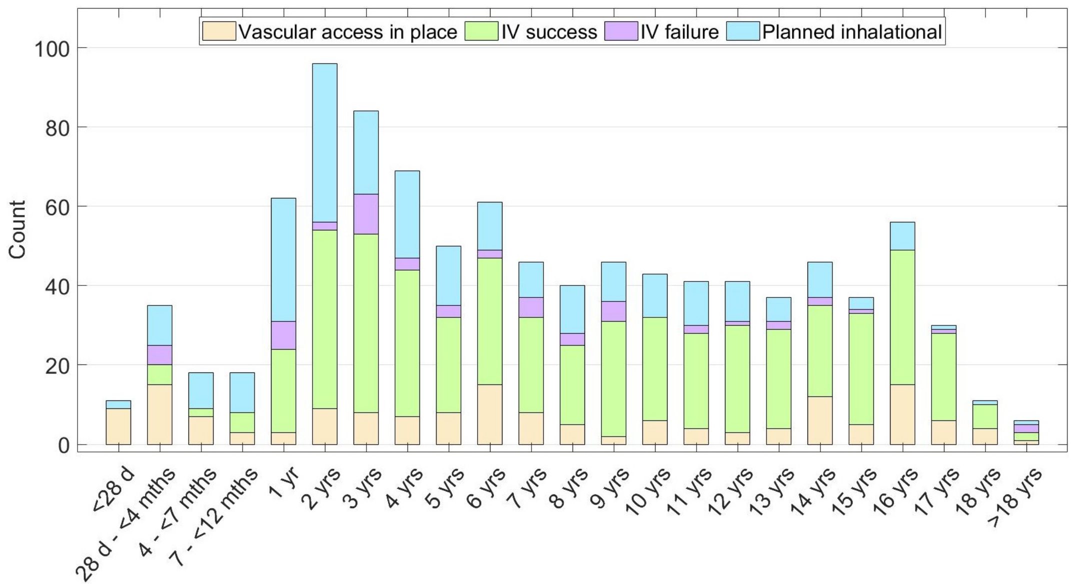

FIG. 7. Breakdown of induction practice and success rates by age

In planned IV inductions, success of IV cannulation varied by age. The highest failure rate was 50 % and occurred in patients of 28 days to <4 months old, and those

>18 years (see Fig. 8) However, sample sizes were small in these age groups.

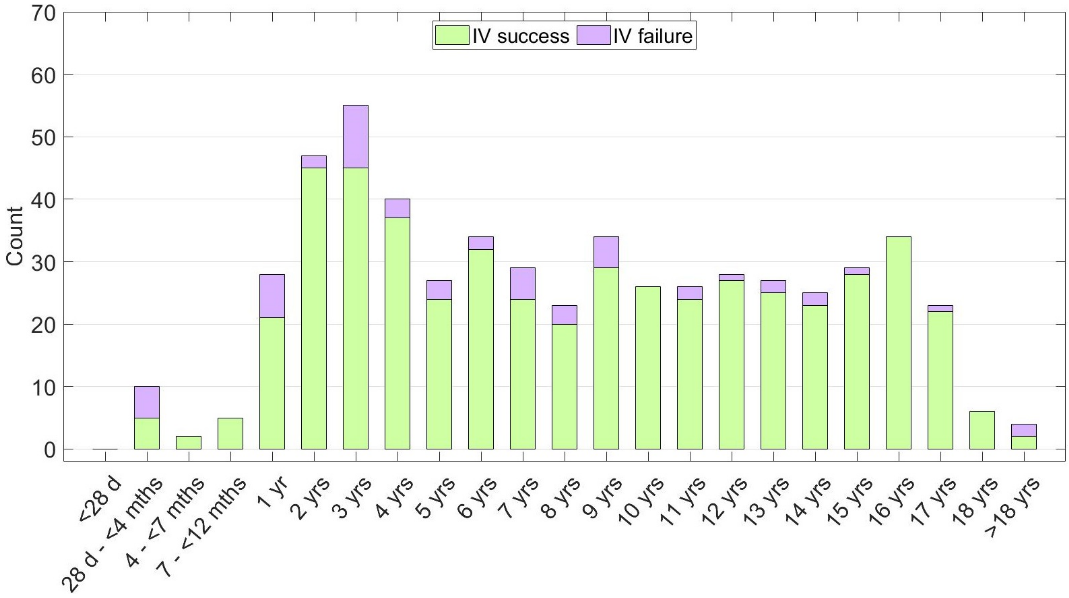

FIG. 8. Breakdown of attempted IV inductions in success and failure by age.

The success rate of IV cannulation varied by provider. Ten anesthesiologists obtained 100 % success rates. The lowest value observed was 74 %, representing a 26 % IV cannulation failure rate.
A wide variability in the practice of TIVA and IH induction was further observed, ranging from 27 % attempted TIVA practice for one provider to 87 % attempted TIVA practice for two providers (compare Fig. 9).

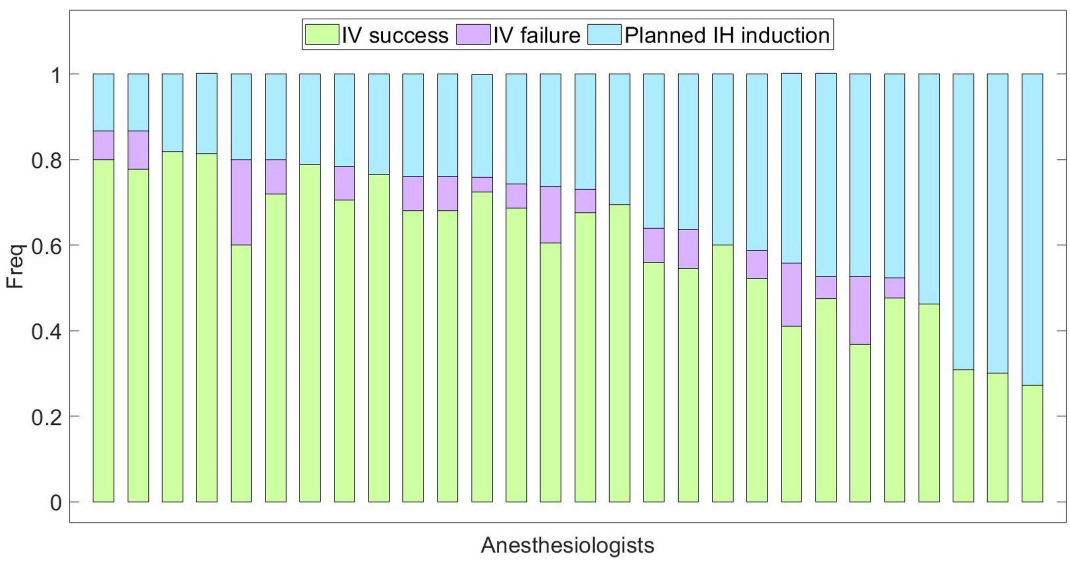

FIG. 9. Variability of TIVA and IH induction practice by provider. The values refer to the overall study population excluding patients with vascular access already in place.

3.1.1.2 Predictors for success Analysis of risk confounders in the IV success and IV failure study population showed significance for the variables anxiolytic given ($p = 0.049$), age ($p \ll 0.001$), behaviour when encountered ($p = 0.021$) and behaviour immediately before IV attempt ($p \ll 0.001$).
The logistic regression was applied to ten risk confounders: age, sex, autism, known pre-existing anxiety, anxiolytics given, previous anesthetic, local anesthetic applied, child's behaviour when encountered, and parental presence. Bi-directional Akaike information criterion reduced the logistic regression model to the following four predictors for success: age, previous anesthetic, behaviour of the child when first encountered (distressed but cooperative or combative). The variables 'age' and 'combative behaviour at first encounter' were shown to be statistically significant with P-values of $P = 0.012$ and $P = 0.027$, respectively. Statistical significance was not shown for other risk confounders (see Tab. 1).
For the variable 'age', the calculated odds ratio (CI) is 1.09 (1.02 - 1.17). With an increase in age by one year, the probability that IV cannulation will be successful increases by 1.09 times (9 %). Thus, as patients grow older, it is more likely to be successful.
Combative behaviour of the patient at first encounter was associated with an decreased likelihood of IV cannulation success (odds ratio (CI) of 0.27 (0.09 - 0.85)). For combative patients, IV cannulation success was 73 % less likely compared to patients who do not show combative behaviour.

	Odds Ratio	**95% Confidence Interval**	**P-value**
Constant (Intercept)	7.20	3.82 – 13.58	≪0.001
Age [years]	1.09	1.02 - 1.17	0.012
Previous anesthetic	0.60	0.31 - 1.15	0.124
Child's behaviour when encountered: Distressed but cooperative	0.76	0.33 - 1.76	0.527
Child's behaviour when encountered: Combative	0.27	0.09 - 0.85	0.027

TAB. 1. Outcome variables of logistic regression optimized by AIC, including odds ratios, 95 % confidence intervals, and P-values.

3.1.2 Secondary outcomes

Secondary outcomes are presented in the order information became available (chronological order of data collection form), and by patient and provider related outcomes.

3.1.2.1 Overview of overall study population Of 984 cases available for statistical analysis, 42 % (413/981) were female with a median [IQR] age of 6.5 [3.5 - 13.0] years. Autism was documented on the patients' charts in 10 % (90/941) of cases. It was the first time undergoing general anesthesia for 45 % (419/934) of patients. An overview of demographic characteristics of the overall study population is outlined in the Appendix Tab. 6.

3.1.2.2 Anxiety and anxiolytic premedication For patients with vascular access already in place, no data were collected on anxiolytic premedication and topical cream placement. Thus, the following results refer to the population undergoing planned IV induction and planned IH induction.

Analysis of anxiety and anxiolytic premedication administered required both variables to be provided. Anxiety was documented in 89/797 patients (11 %), of which 31 % of patients received anxiolytic premedication, thus the remaining 69 % of patients with documented anxiety did not receive anxiolytic premedication. Of 708/797 patients without documented anxiety, 6 % were given anxiolytics preoperatively (see Fig. 10, left side).

Of all patients undergoing planned IV or planned IH induction, 9 % received anxiolytic premedication. Midazolam was predominantly used in 50/68 cases (see Fig. 10, right side), followed by Lorazepam for 6/68 patients, which .

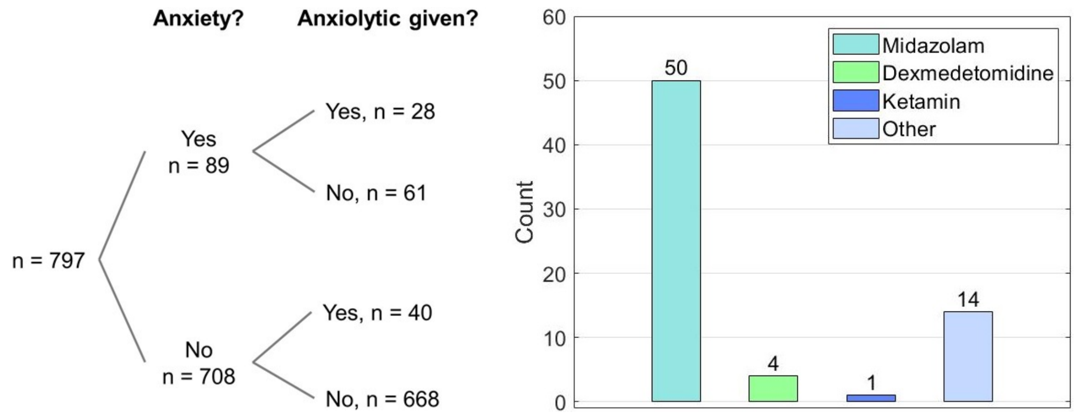

FIG. 10. Left side: Anxiety and proportion of anxiolytics given. Right side: Overview of anxiolytic drugs used. The numbers refer to 68 patients with planned IV and planned IH induction, for whom information on anxiolytic premedication were provided.

3.1.2.3 Topical cream placement The histogram shows a right-skewed frequency distribution of the duration of local analgesic cream placement in the planned IV induction study population, with a peak at 40 - 50 minutes of application time (see Fig. 11).
It is considered unlikely, that local analgesic cream has been applied for more than three hours. It should be assumed that the cream was taken off in the meantime if delays occurred. The actual time point of cream removal was not collected in the data collection form, thus cream was considered to be taken off just before the first IV cannulation attempt to derive duration of placement.
For patients with planned IV induction, the median [IQR] time the topical analgesic cream has been applied on the induction site was 60 [44-90] minutes (see Appendix Tab. 6). Thus, requirements for effectiveness of cream were met for at least 50 % of patients.

Ametop was predominantly used to provide pain relief on the IV cannulation site (390/676, 58 %), followed by Lidocaine in 33 % of patients. (compare Fig. 11).

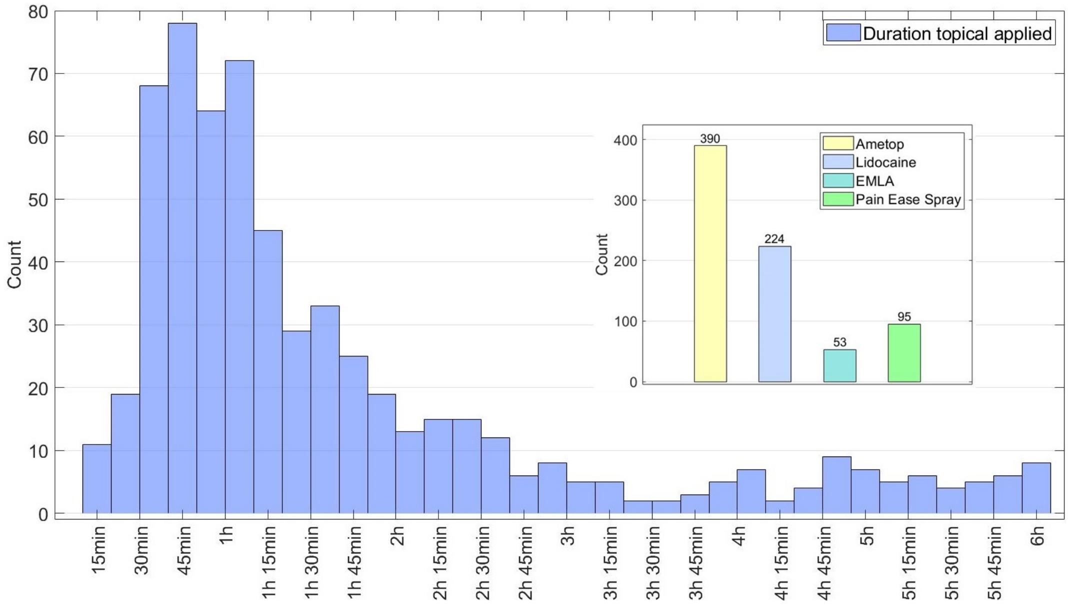

FIG. 11. Histogram of time frame of topical analgesic cream placement. Each bar represents a time frame of 10 minutes. The bar graph displayed within the histogram shows the use of local analgesic cream (Ametop, Lidocaine, EMLA) and the additional use of Pain Ease Spray at the time of IV attempt. The total sample is 525 patients, for whom information on local anesthetic use were provided.

3.1.2.4 Distraction techniques The following options for distraction were available: TV, iPad, verbal distraction, distraction with blowing bubbles, and VR. No distraction was also an option. Verbal distraction was the most frequently used technique in 57 % (312/552) of patients, followed by TV in 39 % (214/552) (see Fig. 12). Bubbles were used in 10 % of cases (57/552), of which all but two were performed in MRI suites. No case was reported with the use of VR for distraction (see Appendix Tab. 6).

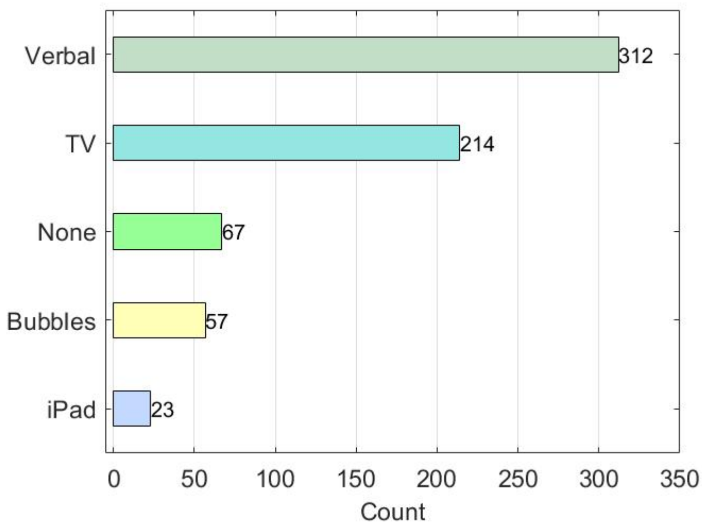

FIG. 12. Distraction techniques used in the planned IV induction study population. Numbers refer to a total of 552 patients with information on distraction provided.

3.1.2.5 Environment during IV cannulation IV cannulation attempts were conducted in the OR in 80 % (448/561). For 15 % of patients, IV cannulation was attempted in the MRI suite (87/561), and 5 % of cannulations were performed in the ACU. A parent was present at IV induction in 89 % (486/549) of cases (see also Appendix Tab. 6).

3.1.2.6 Patient's behaviour at encounter and immediately before IV insertion
Behaviour during successful IV inductions
At first encounter of patient and provider, 84 % (421/501) of patients were calm, 13 % (66/501) showed distressed, but cooperative behaviour, and 3 % (14/501) patients were combative. Regarding the behaviour immediately before IV cannulation, the number of patients with calm behaviour was decreased by 10 %, whereas distressed and combative behaviour increased by 9 % and 1 %, respectively (see Fig. 13, left panel, and Appendix Tab. 6).

Transitions between behaviour categories were seen both ways (towards calmer behaviour, and towards more combative behaviour). Of 421 calm patients at first encounter, 53 patient shifted to distressed but cooperative behaviour, and three 3 patients have changed to the combative category. Four patients with distressed behavior at first encounter changed to calm behaviour immediately before IV insertion, and 5 patients transitioned to combative behaviour. Of 14 combative patients, 13 remained combative immediately before IV induction. One patient transitioned from combative behaviour at first encounter to calm behaviour immediately before IV cannulation; they received a premedication. Transition details are outlined in the right panel of Fig. 13.

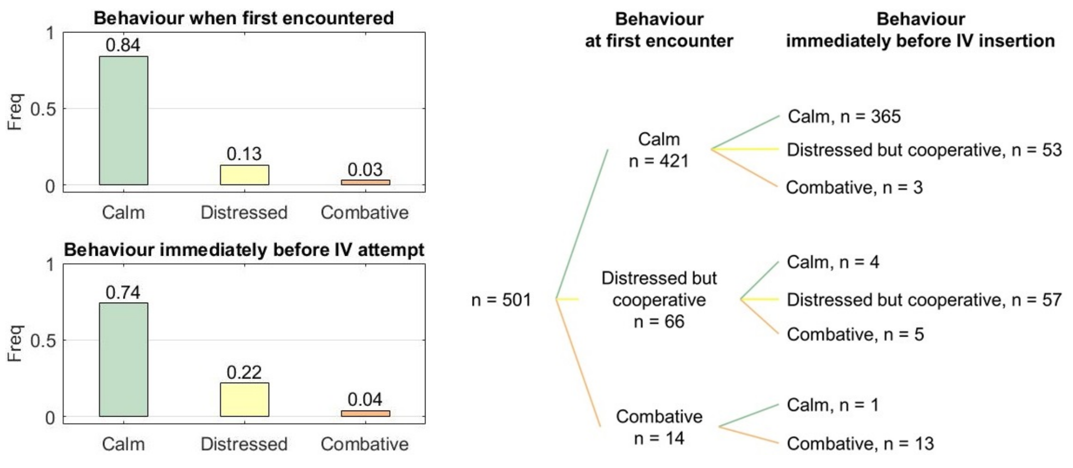

FIG. 13. Overview (left) and transition (right) of behaviour at first encounter and immediately before IV cannulation. Results are based on data for 501 patients with successful IV induction and for whom information on both behaviour variables were provided.

The correlation between anxiolytics given and change in behaviour was further investigated. Of patients without changes in behaviour (Calm - Calm, Distressed - Distressed, and Combative - Combative), 4 % (19/435) of patients received anxiolytic premedication. Of patients who transitioned towards calm behaviour (Distressed - Calm, and Combative - Calm), 40 % (2/5) received anxiolytic premedication.

Behaviour during failed IV inductions
In the IV failure population, 73 % (41/56) were calm, 18 % (10/56) distressed, and 9 % (5/56) of patients showed combative behaviour at first provider encounter. Immediately before the first IV attempt, the number of patients with calm behaviour was decreased by 18 %, resulting in 55 % (31/56) calm patients. Distressed and combative behaviour of patients increased by 13 % and 5 %, respectively (see Fig. 14, left).

Behaviour changes from one category to another were limited to one way in the failed IV induction study population. If a change in behaviour appeared, it was only towards the more combative behaviour category, not becoming calmer. Of patients with calm behaviour at encounter, 9/41 patients shifted to distressed behaviour, also one patient showed combative behaviour immediately before IV insertion. Of 10 distressed patients at first encounter, 2 patients shifted to combative behaviour. Patients who have been combative at first encounter remained combative immediately before cannulation in the failed IV induction study population (see Fig. 14, right panel).

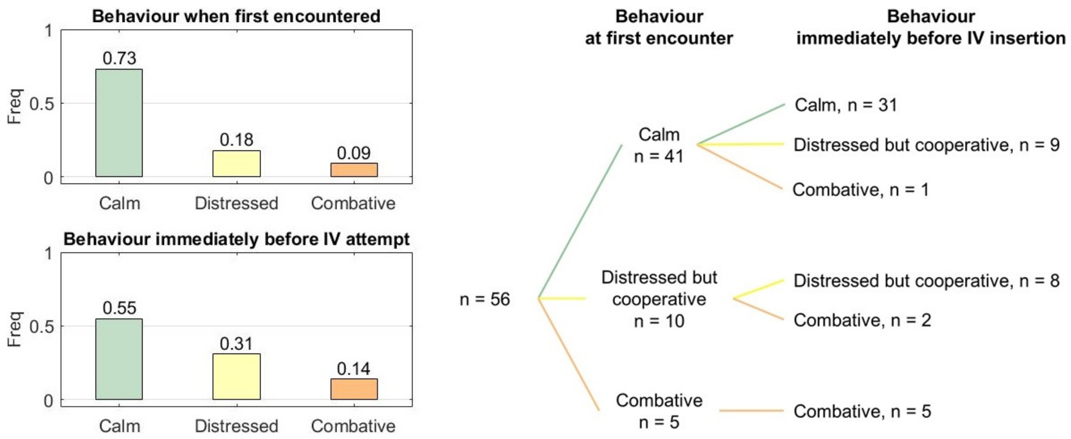

FIG. 14. Overview (left) and transition (right) of behaviour at first encounter and immediately before IV cannulation. Data from 56 patients with failed IV induction and for whom information on both behaviour variables were provided are presented.

Patients who did not change their behaviour from first encounter to immediately before IV insertion received anxiolytic premedication in 14 % (6/44). Of patients with transition towards combative behaviour, 9 % (1/11) of patients were premedicated with anxiolytics. Thus, anxiolytic premedication was ineffective in those patients.

3.1.2.7 Reaction on skin and vein puncture No reaction on skin and vein puncture was observed in 332/488 patients (68 %) in the IV success study population, and in 10/49 patients (20 %) with failed IV inductions. Inductions with none or slight reactions were achieved in 453/488 (93 %) of successful IV induction cases, and in 31/49 (63 %) of failed IV inductions (for allocation criteria see 2.3.3). Severe reactions were higher in the failed IV study population when compared to the successful cases, with 18/49 (37 %) and 38/488 (7 %), respectively (compare Fig. 15).

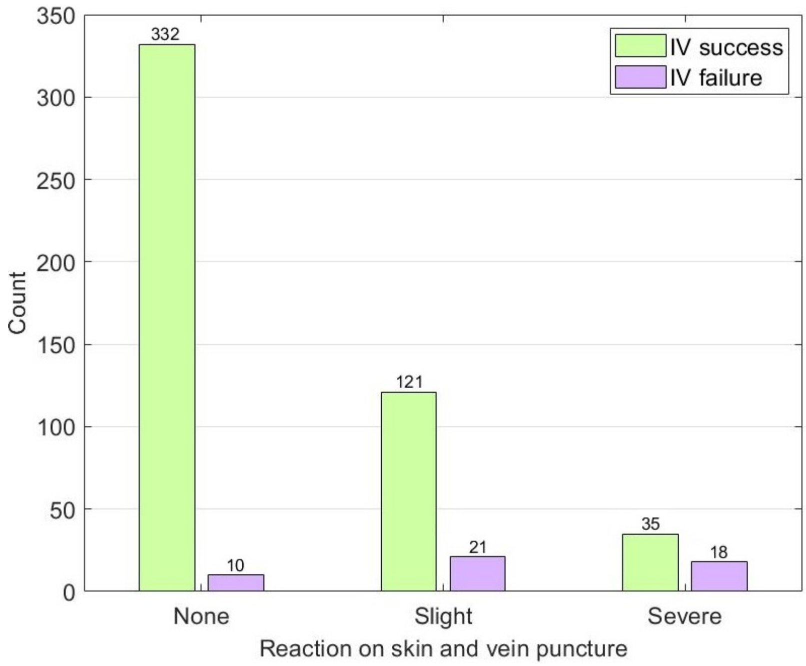

FIG. 15. Comparison of painless, slight, and severe reaction to skin and vein puncture cases by IV success and IV failure.

3.1.2.8 Attempts and provider Attending anesthesiologists provided 296/559 (53 %) of first attempts, and residents first attempted IV cannulations in 175/559 (31 %) of patients. The median ages of patients in which the attending anesthesiologists or residents performed the initial IV attempt were 8.5 years and 9.5 years, respectively. For unsuccessful first attempts of residents, the median age of patients was 7.5 years. The median age in patients with first attempts failed by anesthesiologists was 3.5 years.

In 32 cases in which residents have failed the first attempt, anesthesiologists took over in 15 cases, residents attempted a second time in 16 cases, and a fellow took over in one case. The median age of patients, in which anesthesiologists conducted the second attempt was 10.5 years. The median age of patients in which the resident attempted a second time was 11.5 years.

Pain on propofol injection was reported in 43/468 (9 %) of successful IV inductions.

3.1.2.9 Practice variability of attending anesthesiologists The practice of anesthesiologists varied in the proportion of anxiolytics given, planned inhalational induction, application of topical analgesic cream, parental presence, distraction techniques used, among other factors evaluated (compare Fig 16). Practice related outliers were found in the administration of anxiolytic premedication, topical cream placement, IV cannulation success rate, the use of iPads and bubbles for distraction, and the use of no distraction (see values Appendix Tab. 8). Verbal distraction showed the largest range of values not considered outliers: 0 - 92.3 %.

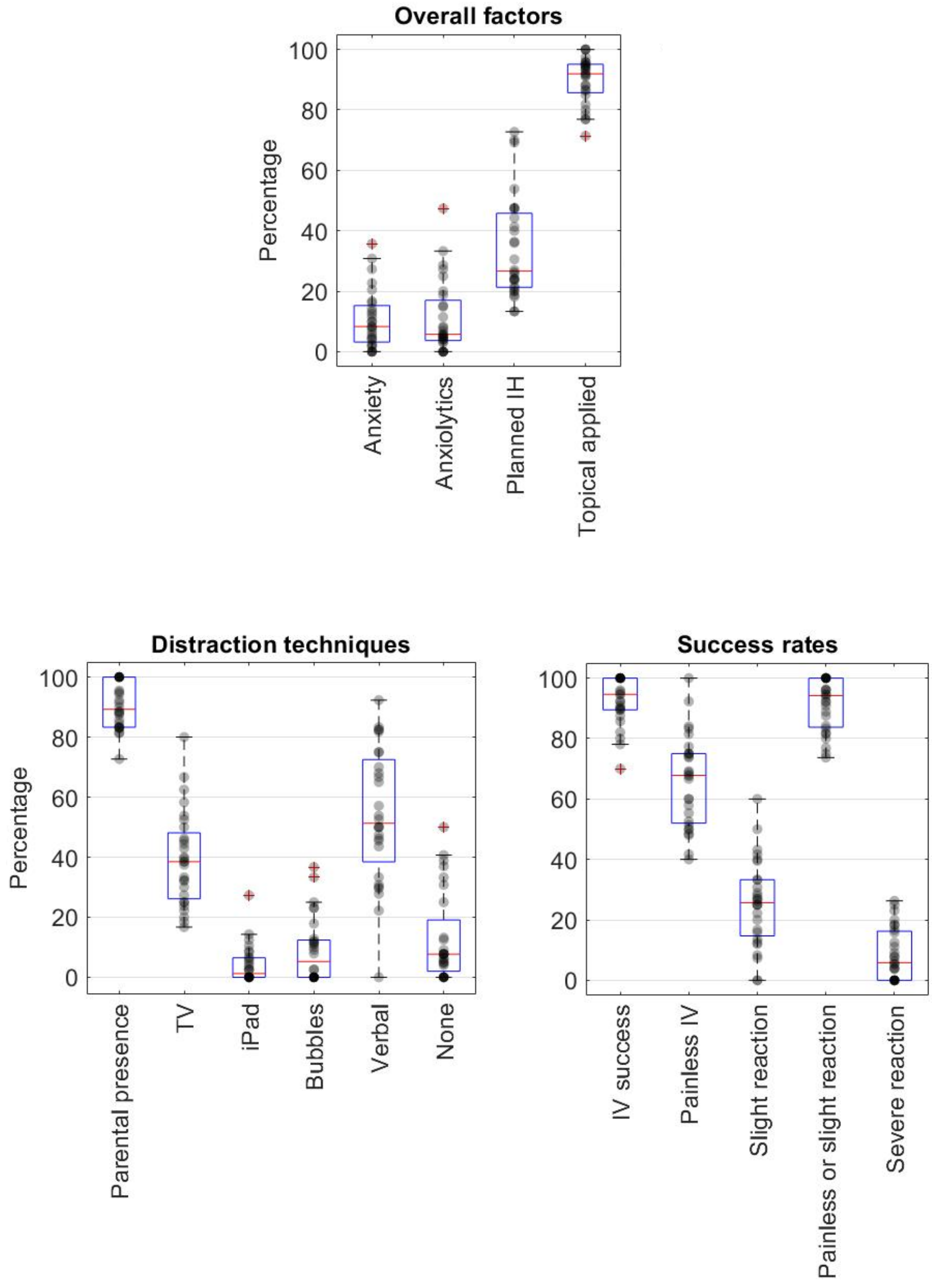

FIG. 16. Variability in practice by attending anesthesiologist. Grey dots represent individual attending anesthesiologists, red bars indicate median values, interquartile ranges are indicated by blue boxes, and red target crosses mark outliers. The top subplot shows success-related factors of overall population, the bottom subplots show variability in distraction techniques and technique success rates in patients for whom IV cannulation was required.

3.2 Part B: Semi-structured interviews

Eleven anesthesiologists and two OR nurses participated in semi-structured interviews between 2019-01-15 and 2019-02-28. Data are presented separately for each question in the order in which the questions were posed.

3.2.1 Overall data

The most frequently used word by the interviewees was 'child' (n=298), followed by 'distraction' (n=85), and 'parent' (n=83) (see Fig. 17, see Appendix Tab. 9 for quantities). Since 'child', 'kid', and 'patient' were considered synonyms in the context of the interviews, 'child' refers to the entire pediatric population at BCCH.

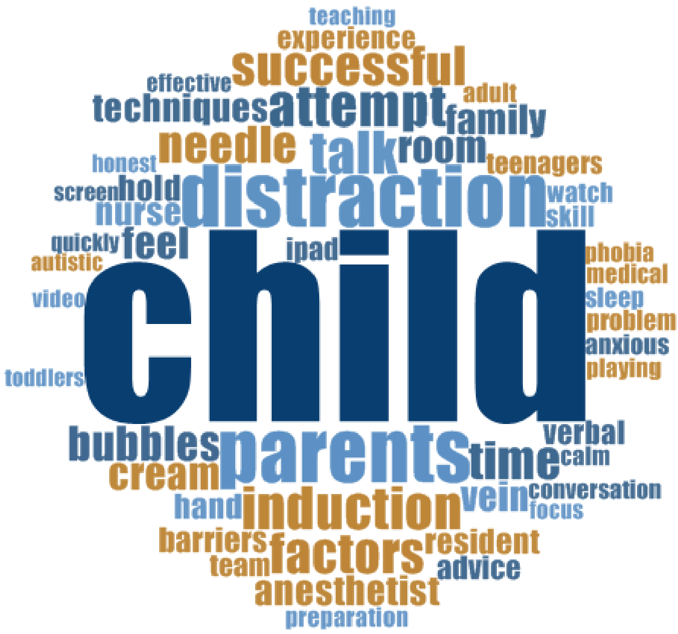

FIG. 17. Word Cloud: The 50 most frequent words as used by the interviewees. The larger the font size and bolder the font, the more often a word was mentioned. The minimum word length used to identify words for inclusion in this word cloud was four.

3.2.2 Factors contributing to a successful IV attempt

Factors contributing to a successful IV attempt were grouped into categories. Categories most frequently mentioned by the 13 interviewees were distraction (n=13), family preparation (n=10), parental presence (n=10), support of the OR team (n=8), topical cream placement (n=7), child behaviour and coping strategies (n=6), among others.

Cluster analysis with circle graphs provided further details on correlation between words (words that are often mentioned in the same context) (see Fig. 19, for quantites see Appendix Fig. 10).

Five themes emerged in this circle graph: a) approach (family - parents - preparation – experience), b) distraction (distraction – key), c) skill (anesthetist - skill – successful), d) teamwork (team - holding – nurses), and e) communication (communicate – talking).

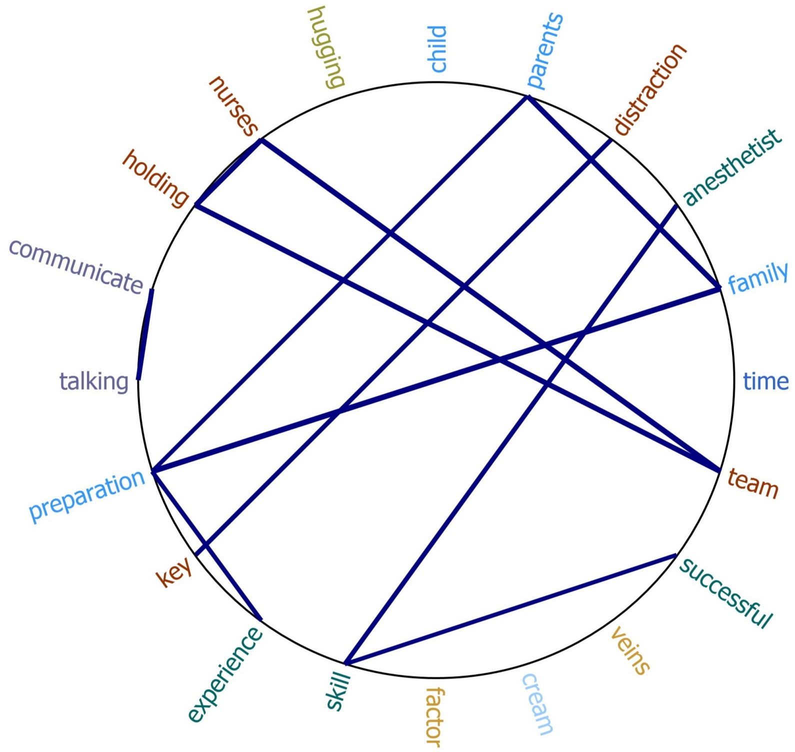

FIG. 18. Circle Graph Q1. The 20 most frequently used words on the perimeter, starting from child then going clockwise. Correlation is indicated by the blue lines that connect the 20 most frequent words shown on the perimeter, and by similar colour of words. Correlation with index <0.7 are suppressed in the visualization.

The strongest correlation exists between family and preparation. clusters, visible by the same colour of words, also indicated a relationship between Words that were not connected, such as veins and factor (beige).

Further analysis of both categories and circle graph resulted in the collapsing of related themes into seven main themes: family preparation, child, anesthesiologist, team support, topical cream placement, OR environment, and cannula placement (see Appendix Fig. 26, blue boxes).

3.2.2.1 Family preparation Family preparation was mentioned by 10/13 interview participants. For a successful IV induction in pediatric patients, it is seen to be crucial to prepare and communicate with the family preoperatively about what is going to happen in the OR: *"If the parents are told right from the beginning that the expectation is IV start, that usually already sends you towards success."* [P1]

Addressing individual concerns of the family regarding anesthesia was also mentioned by some interviewees. This was further stressed to be important, particularly if the anesthesiologist's plan differs from the expectation of the family: *"I think usually if there's doubt or uncertainty on part of the family about why we're going to do an IV, me having a conversation with them and explaining what I'm going to do, and why I'm going to do it, and how likely I think to be successful."* [P5]

Getting the family on board with the plan, whether it is a planned IV induction or a planned IH induction, was mentioned to be a priority for 5/13 interviewees.

Therefore, anesthesiologists talk to the family and respect their wishes, if possible: *"They see that there is somebody that listened to me and worked with me, and then they are on your side. And even if it doesn't go perfectly, they'll be supportive and they'll say to the child it's okay. [...] And I find that buy-in that gets from the parents is just the most valuable thing that you can possibly get, no matter how it goes."* [P9]

3.2.2.2 Child A total of 5/13 interviewees commented, that the approach of induction is highly dependent on factors related to the patient. Thus, the optimal approach needs to be individualized for each patient: *"I think that really the key things are that you tailor your approach to the patient and the patient's family, so that you don't have that fixed idea of what you're going to do for every patient."* [P9]

In this context, two prominent factors with significant impact on the approach and outcome were reported: a) The patient's behaviour and coping prior to induction is seen to be crucial by 6/13 participants, such as illustrated by *"I would say that the first most prominent factor would be the behavior of the child. So that's going to be the number one determining whether you're going to be successful."* [P8], and b) the age and developmental stage of the patient are also considered to play a key role by 3/13 participants: *"Taking into account the patient's developmental stage or age and then using techniques that are appropriate for that."* [P7]

Six of 13 participants mentioned, that a calm and cooperative patient facilitates the placement of an IV cannula, whereas an uncooperative patient impedes the process: *"A major factor is the child's cooperation just in terms of staying still. If they stay still, then it's easy. If you're fighting them, or they are trying to move, it becomes technically more difficult."* [P10] Two participant further stated that especially anxious, upset, distressed, or uncooperative patients will benefit from anxiolytic premedication.

3.2.2.3 Anesthesiologist The insertion skills of the provider were seen to be important by 4/13 interviewees. In a broader context, 2/13 interviewees further stated, that experience makes a difference: *"The experience of the person doing the IV is really critical. So if you have a staff pediatric anesthesiologist who works in an IV induction center and does this all day long, your success rate will be higher. And not only will it be higher, but the quality of the experience for the patient will be better, too."* [P9]

Good communication skills were mentioned by 3/13 participants. One aspect is the anesthesiologist's communication with the patient: *"One of the big things is, before they (patients) come into the operating room, trying to establish a relationship before that, so that you are a familiar face, and I try to pick out something that we've already talked about and then bring that back up again."* [P12]

3.2.2.4 Team support Support by the OR team and preoperative nursing was identified by 8/13 interviewees as a factor contributing to a successful IV cannulation. The team is engaged in various tasks to facilitate the attempt of the anesthesiologist: *"Everyone on the team has to be on board with it, including preop nurses and how they sell it to the family when they put the cream on, to the preparation of the nurses in the OR, how they're willing to help with distraction or holding."* [P1]
Three interviewees further emphasized, that *"it's a team thing. I don't think I can take my skill set, turn up at a random hospital where they are not used to putting IV's into children and just start doing it."* [P5]

Communication between the team and the anesthesiologist was also seen to be important by 2/13 participants: *"If I have a great anesthetist, that has good communication skills and is able to communicate what we're doing in a way that is going to allow us to work with that kid, then I know that I'm going to be less involved in trying to make it work."* [P8]

A good team dynamic has further been identified as a factor for success: *"The dynamics between the nurse, the patient and anesthesia are very cohesive and you don't even have to talk much, because the focus is talking and communicating with the patient."* [P8]

3.2.2.5 Topical cream placement The use of topical analgesic cream *"makes a huge difference"* [P2], and is considered to be essential for IV cannulation success by 7/13 interview participants. More specifically, having an adequate amount of cream in the right place, and giving it time to work was found to be important: *"I think effective use of the creams, so allowing them to be on for the amount of times that they need to be on and not rushing through."* [P4]
One interviewee also suggested to additionally use freezing spray in older patients, but also mentioned that it can cause distress in younger patients due to the cold sensation.

3.2.2.6 OR environment Many facets of the OR environment during IV induction have been identified to contribute to cannula placement success, such as the operating room design, parental presence, and child-dependent adjustments of the environment.

The newly designed operating rooms of BCCH were mentioned as factors by two participants, since *"a happier environment in the new OR's is capturing the kid's attention with friendlier rooms, pictures on the walls, and videos playing. The walk-in and "oh my god this is horrible", like in the old operating rooms, isn't seen that much anymore."* [P1]

Parental presence during induction was mentioned to make a difference by 10/13 interviewee participants, not only prevent separation anxiety. Five of thirteen interviewees shared the opinion that the less emotional and calmer parent should be chosen to attend induction of anesthesia: *"Having a parent in there is highly dependent. Some of the parents are amazingly helpful and do all the right things and are the most useful thing that you could ask for. Other ones can be either not helpful, or actually counterproductive"*. [P9] It was further mentioned by P10, that *"in general, a calm parent makes a calmer child."* The parental role during induction is considered rather supportive than active: *"Parents will do the special hugging, but are not so good in distracting."* [P1], and *"have the parents in their face smiling, encouraging them and letting them know it's okay."* [P7]
Depending on the relationship between patient and parent and the child's age, the level of engagement of the parent varies. For teenagers, the relationship between patient and parent is carefully assessed: *"When they're not close with their parents at all and they are a teenager and you can see it's awkward [...], it's actually just you and that teen dealing, and Mom just happened to be a bystander. So it's not bringing that person in to assist with it."*

Adjusting the environment to the individual needs of a patient was identified to play a role, too, such as having fewer people in the room: *"When we have an autistic kid, it's the absence of a team that often makes it successful, since people themselves and* *people being present are what the problem is sometimes. [...] And in other children it takes the whole village, it takes the parent to be present, and staff for distracting and holding, enabling me to do my job."* [P7] Depending on the patient, adjustments of OR environment may also include dimmed lights, noise regulation, or warm blankets: *"I always make sure I bring a couple of warm blankets with me, and particularly for teenagers I try get them to lie down and get them covered. You know that they're uncomfortable because they cross their feet. Everything becomes too close, so then I bundle them, I tuck them in all the way down and what I can see is that they feel comfy and protected."* [P8]

3.2.2.7 Cannula placement Factors directly related to the cannula placement include distraction during induction, positioning, speed, visibility of veins, and equipment.

All 13 interviewees identified distraction as a key facilitator for IV cannulation success, *"but age appropriate for all of them."* [P8] One participant further stated, with a good distraction technique *"you can almost get away with ineffective cream, not always though."* [P2] However, four participants also mentioned that some patients do not want to be distracted, but actually would like to watch what is happening. Watching the IV cannulation process is also encouraged if preferred by the patient.

Three of 13 interviewees mentioned the positioning of the patient: *"It's always the easiest when the patients are cooperative and just hop up on the bed, [...] you're increasing your chances of getting the IV in."* [P8]
Also, the special hug is seen to be a major facilitator by two interviewees: *"The special hug is key. Most kids handle or respond to their parent better during the special hug. It is suitable for almost all children that are able to sit."* [P1]

Being speedy, effective, and efficient is considered to be enormously important by 5/13 interviewees. *"The faster we can get them to sleep the better for them."* [P8] A threshold time, which also depends on the patient, was further described by P9: *"They come in and they come down this hall, people are pointing out things on the walls. Then, people start holding their hand, and then they are wondering "okay, what's going on". There is kind of a short window of time, when they are figuring out what's going on here, that you have, and you got to get it done in that window. And if you do you'll be fine. But if you don't, once they lose it and decide "I'm not happy" and start fighting, you've lost your chance."* [P9]

The visibility of veins, *"whether they are superficial, whether they are present and they are straight"* [P10] was mentioned by 2/13 interviewees. Two participants further stated that they would not go for a vein unless they are confident in being successful.

The equipment is seen as a minor factor by one participant, more specifically the type of IV or its size. Three participants mentioned a tourniquet to be helpful, too; however, it should be positioned *"as close to the vein as possible. Some people have it on the top arm when doing an IV start in the hand – that's the best predictor of failure."* [P4]

3.2.3 Barriers to a successful IV attempt

Factors that pose a barrier to a successful IV attempt were grouped into categories. Interviewees most frequently mentioned the categories needle phobia (n=10), child

behaviour (n=7), analgesic cream (n=7), and anatomy (n=8) as barriers.
In a circle graph, the following themes emerged among the 20 most frequent words used (see also Appendix Tab. 11): a) needle phobia (needle - phobia - barrier - child), b) cream (cream - time - nurse), c) parent (parent - anxious), d) induction (induction - reasonable), e) distraction (talking - distraction), f) time (time - nurse - anesthetist), and g) veins (difficult - veins). The strongest correlations exist between needle and phobia, as well as time and nurses.

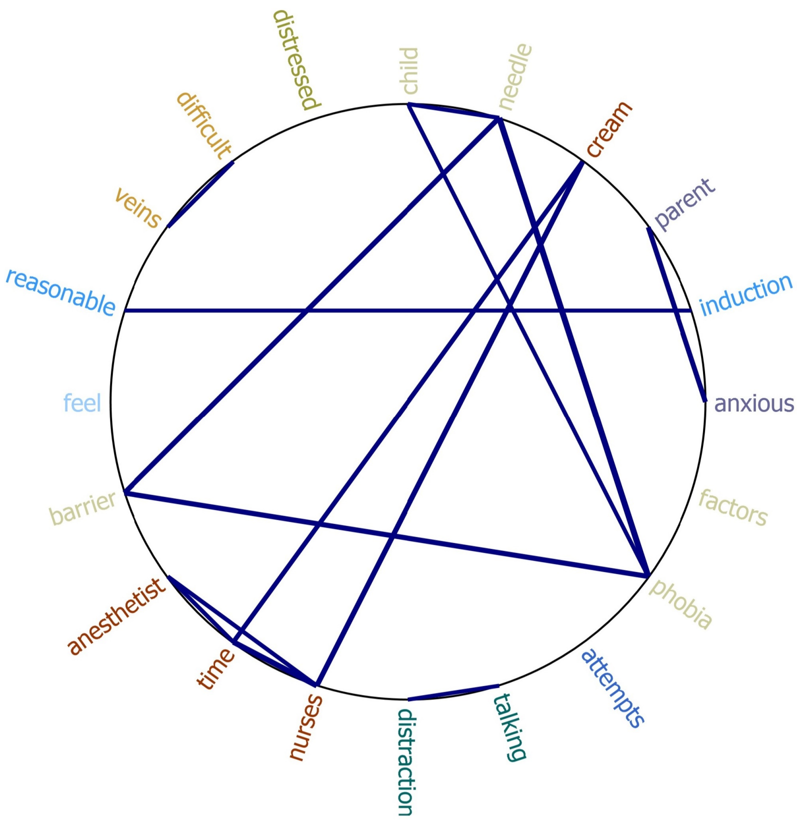

FIG. 19. Circle Graph Q2. The 20 most frequently used words on the perimeter, starting from child then going clockwise. Correlation with index <0.6 are suppressed in the visualization.

Further analysis of categories and circle graph resulted in seven main themes: child, parents, analgesic cream, cannula placement, distraction, team, and anesthesiologist (see Appendix Fig. 27).

3.2.3.1 Child The majority of interviewees (10/13) identified needle phobia as the biggest barrier to a successful IV induction. Eight interviewees agreed, that they *"won't push them (patients) to get the IV unless there's a reasonable reason to do it"* [P4], and usually switch to inhalational induction in patients with fear of needles. One interviewee mentioned, that *"I don't just accept it actually, I try to get them out of that [...] But for sure, if a kid is really needle phobic, I would give them gas – but I would definitely have the conversation."* [P3], whereas another participant stated: *"If it's a one-time procedure, I don't usually make an effort to try to coach them through it. If children come repeatedly then we get psychology involved. [...] It's very, very difficult to get over that barrier."* [P1] It was emphasized by one interviewee to *"recognizing where you're not going to be successful because they have such a barrier, or they don't even want to come into* *the room."* [P8] One participant reported to sometimes use premedication in such cases.

A barrier mentioned by 9/13 interviewees are uncooperative, distressed, anxious, or upset patients: *"If it's a big kid that is so uncooperative that it becomes challenging, and I decide in the moment that the least traumatic way to go off to sleep is with the mask, then I'll make that decision."* [P5] Fighting, kicking, or withdrawal of hand of upset patients may impede IV cannulation according to P13. Another interviewee reported to *"not even try to hold them down to put an IV in, I just use a mask."* [P3]
For some patients, *"just the act of holding them and not letting them see their hand makes them upset."* [P12]. This is considered counterproductive for a certain population, such as cardiac patients: *"I don't want the kid to be distressed because it's not good for their physiology. So actually, in that case, I usually premedicate them and then do a mask induction for that reason, it's less stressful."* [P11]
The child's expectation and reaction to an IV attempt was also identified as barrier by one participant: *"If they don't think they're going to feel anything, and when they do, sometimes they get really upset. So, I try to tell them that they still may feel a little bit of a poke."* [P12]
Patients, who previously experienced IV cannulation attempts that have gone poorly or had pain, may be more anxious and IV cannulation may become more challenging, according to P12.

3.2.3.2 Parents Parents were mentioned by 8/13 participants to be *"sometimes not helpful."* [P3] Especially anxious parents are considered a major barrier to a successful attempt by 5/13 interviewees: *"It never ever helps to have an anxious parent with a child because the child feeds of their anxiousness, like they know that their parent is upset, or worries, or is crying. [...] And then also it usually takes away our focus on the child, so then we're focusing on the parent, especially when they are over-anxious so much though that they are passing out on the floor."* [P13]

Additionally, 7/13 interviewees identified parental expectation to be a reason not to try an IV induction in the first place: *"If I'm discussing with the family and I feel that they have a reasonable claim to requesting an inhalational induction straight off the back, [...] who have experienced both inhalational and intravenous induction and can make an informed choice what they prefer, the former over the latter. I don't usually accept that if the family has never had an IV before, or if they had a bad experience somewhere else. I would usually try and persuade them to let me have a look and see, if I can revise their impression of how this can go. But obviously, if they insist, then that's a lack of consent."* [P5] Another participant pointed out, that *"if they (parents) really want a mask induction, the mask induction can't go badly enough to make the them think that that was a bad choice, and the IV induction can't go well enough to make them believe that was the better choice."* [P10]

3.2.3.3 Analgesic cream Problems associated with topical analgesic cream placement were reported to be a barrier by 7/13 interviewees. *"Not waiting long enough for the creams to work"* was mentioned by 6/13 interviewees, as it may result in ineffective dermal analgesia. P9 explained, that *"the people who put it on aren't people who start IV's. So, they don't know where best to put it on, they guess, it's often not in the right spot."* This was identified as a barrier by 3/13 interviewees. The size of the sterile dressing that is applied to cover the cream was another factor 1/13 participants commented about, since it is found to be too small. The concentration of the cream was further mentioned by 1/13 interviewees: *"Sometimes it gets smeared around, so it's not concentrated on the right area."* [P12] Not only ineffective cream, but also *"no cream is quite a strong contraindication. I almost never do an IV unless there is*

cream on. That's the main barrier. Unless the kid is older and the kids tell the nurse that he or she doesn't want cream and is happy to have an IV without it, then it's fine." [P11]
According to another interviewee, cream is often not applied on younger patients because they didn't want it. However, the nurse may not have communicated that to the anesthesiologist, which is considered to be a barrier to a successful IV attempt.

3.2.3.4 Cannula placement An unfavorable anatomy, more specifically poor and/or difficult veins, were identified to pose a barrier to attempt a cannula placement by 6/13 interviewees: *"There are obviously children in whom you know, or you can see on examination, that it's going to be really challenging. [...] If the child is overweight, or very chunky, and then you can reasonably anticipate that it might potentially be difficult."* [P5]
Three participants further mentioned that they would not try more than twice. *"I think it's a better idea to go and move on to your Plan B quickly, so that the child doesn't remember: I went into this room full of strangers with people talking to me, and all they did was stab me many times, and it hurt'. They are going to remember that."* [P13]

Another factor mentioned by one interviewee, are sudden movements during the attempt: *"Movement is very difficult to deal with. [...] Even a small child can make little movements. They can't make big movement, but they make little movements all the time. You can't keep them perfectly still. So, you have to learn to deal with that."* [P10]

3.2.3.5 Distraction Distraction related barriers were identified by 4/13 participants. One interviewee reported that too many people being involved in distracting the patient may not be effective as a single person doing so: *"One of the things I find that really puts kids off is too many people talking at the same time, like too many nurses trying to distract. And the anesthetist is trying to teach, and then they are trying to say something, it's just too much going on."* [P13] On the other hand, not enough distraction may also be counterproductive according to P13: *"Either too many people talking or not enough distraction, it can go two ways."* Using too many TV's for distraction in the OR was also reported to be a barrier by one participant.

3.2.3.6 Team Four of 13 interviewees mentioned, that *"too many people in the OR"* [P3], and *"too much talking"* [P1] of the team poses a barrier to a successful IV attempt. However, one participant stated: *"I don't think that activities by the OR team has any influence on success, I mean the team is quite focused."* [P2]
One participant further mentioned, that the team wearing surgical masks while the patient is not yet sedated may frighten or increase anxiety of young patients, *"so I always put my mask down."* [P3]

3.2.3.7 Anesthesiologist Anesthesiologist related factors were identified by 3/13 interviewees, such as delays of onset when *"anesthesia got held up somewhere or we can't do the sign in"* [P13]. One participant further explains: *"The sign in is lot of technical talk, and all of that tends to delay the actual onset of the IV attempt. So, a child that is particularly anxious has rising anxiety with delays"* [P1].
A barrier mentioned by two interviewees is the fact, that BCCH is a teaching facility: *"We have to balance letting trainees do things, and the needs of the patients and the quality of the experience for the patient. [...] Some of them (trainees) are much better than others, and none of them, almost, are as good as me or as good as any of us who do it all day long. Trainees don't have the experience. They are not staff pediatric anesthesiologists, so they can't be expected to."* [P9] A participant further explained: *"The more attempts that you do, the harder it is. So, I think it's important to know when to stop the trainee from*

continuing on, and just stepping in and going ahead in doing it." [P13]

3.2.4 Distraction techniques participants think work best

For Question 3 ("Which distraction techniques do you think work best?"), the most frequent words used were child (n=75), verbal (n=51), TV (n=51), bubbles (n=38), and iPad (n=28) (see Fig. 12).

Interviewees were asked about the top three distraction techniques, however, some provided more or less than three answers (see Tab. **??**). More than three distraction techniques were listed, when distraction techniques were considered equally effective, or further information was provided by the interviewee. Less than three techniques occurred once, at which point no further information was provided. Blowing bubbles and verbal distraction were mentioned by 12/13 interviewees to be the best techniques. TV is seen to be effective by 10/13 interviewees, followed by 6/13 who find the use of iPads helpful. VR is considered effective by 2/13 interviewees. Four other distraction techniques, such as distraction by book, toy, phone, or stuffed animal, were mentioned by 5/13 participants.

The majority of interviewees (10/13) think that distraction techniques are highly dependent on the patient, their age, and their developmental stage. The latter two are considered key metrics to select, which distraction technique is most likely going to work. This is further illustrated by the circle graph, with emergence of the following three themes: a) age (distraction - age), b) teenager (verbal - teenager - distraction), and c) children (TV - screens - child; bubbles - interactive - time - child) (see Fig. 20). The strongest correlation is identified between verbal - distraction, and TV - screens.

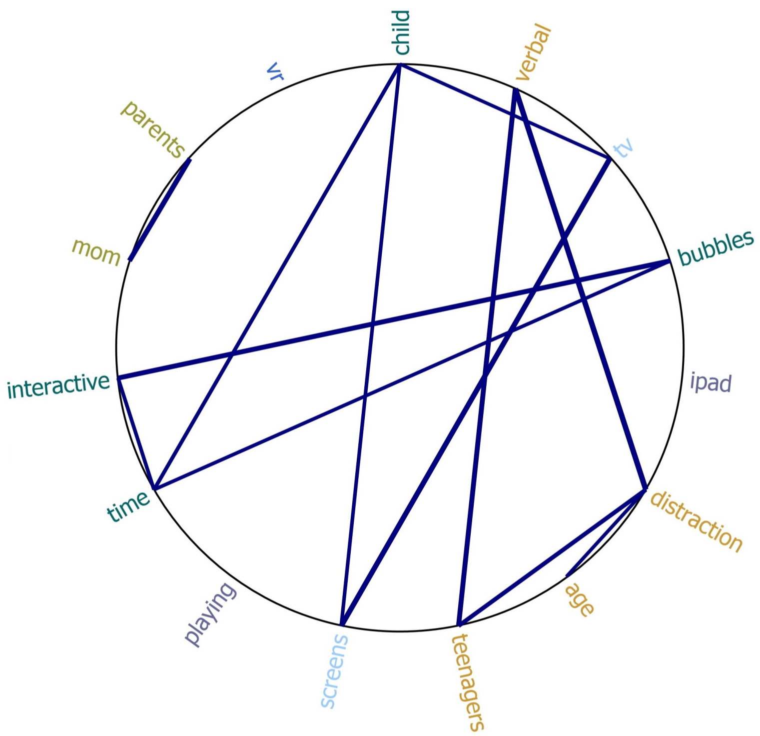

FIG. 20. Circle Graph Q3. The 15 most frequently used words on the perimeter, starting from child then going clockwise. Correlations with index <0.6 are suppressed in the visualization.

3.2.4.1 Blowing bubbles Blowing bubbles is the preferred choice of distraction by 12/13 interviewees, and works best in pre-school children (compare Fig. 21, purple bar): *"The little ones, one and above to about three or four years of age, absolutely the interaction of blowing bubbles I think is marvelous [...]. The bubbles are what kids are focused on because it's interactive, something they can do, they're taking deep breaths, they're participating."* [P1]
According to the interviewees, bubbles are best in capturing the attention of toddlers. One interviewee further stated that even if the patients feel the poke, they may not get upset due to the joy of bursting bubbles: *"I put in the IV, they kind of pull away and they look for a second, and then they go back to bursting the bubbles. They felt it, but they just don't care. They are so happy about the bubbles, it works."* [P9]
One interviewee mentioned, that *"bubbles made it easier to connect with kids"* [P10], which is also identified as facilitator for IV cannulation success in the first interview question.

Since blowing bubbles is not allowed in the main OR suites anymore due to infection control concerns, this distraction technique is limited to MRI suites. However, many participants said that *"if we were allowed to (in the ORs), I would certainly use bubbles."* [4]

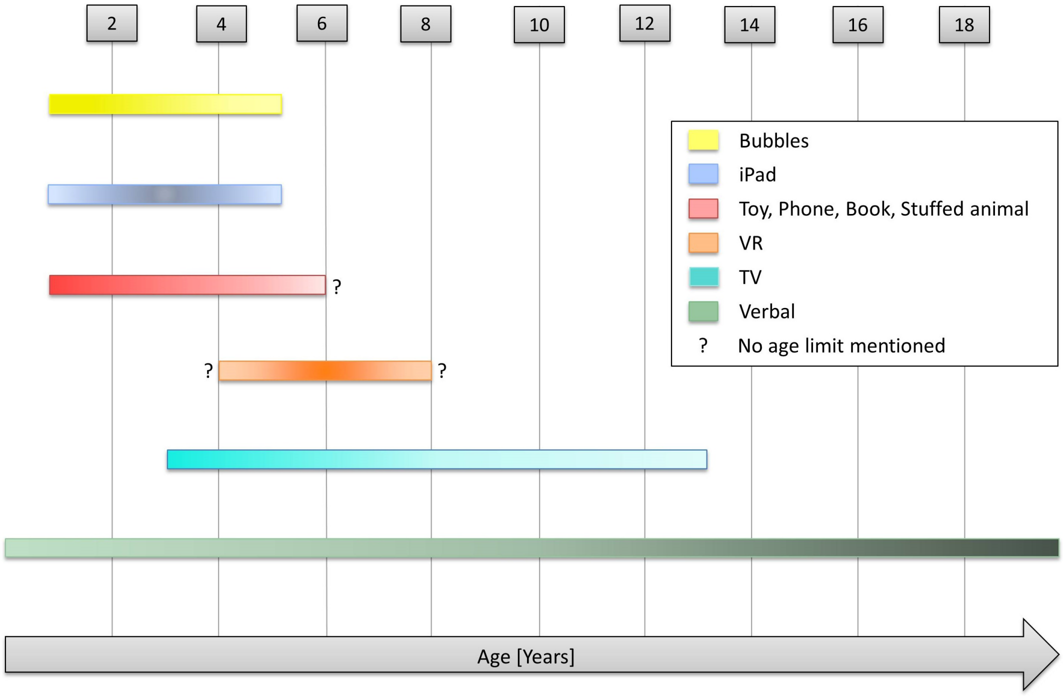

FIG. 21. Distraction techniques by age based on interview data. The widest age limit mentioned is illustrated for each of the six distraction techniques. A question mark indicates that no age was mentioned by interviewees for the upper/lower limit. The intensity of colour emphasizes the suitability for the age group.

3.2.4.2 iPad The iPads were implemented as default to bubbles for pre-school children under the age of five years (see Fig. 21, light blue bar). Whereas 6/13 interviewees reported, distraction with iPads works well in selected cases: *"iPad with apps, such as potato man and you have to put hair on it, they were amazing"* [P3], 4/13 are less convinced: *"I haven't seen a lot of success with somebody bringing in an iPad in the room."* [P1] Also, 3/13 interviewees share the opinion that it is less effective than TV distraction. Associated problems with iPads are the child can only use one hand for playing, and the iPad needs to be held during distraction.

3.2.4.3 Others: Book, Toy, Phone, Stuffed animals Things that the child brought from home, such as a toy or a stuffed animal, work well in younger pre-school children (see Fig. 21, red bar): *" It's going to be a toy or something close that they can hand, something interactive with their hands when they're holding it."* [P8]
P9 mentioned, that the parent's phone can be effective, too: *"If they are already playing a game on the phone, it's amazing, you just bring some kids in and they not even know that they've been moved in. Some kids do well with that but it's kind of selective."*
Two participants also suggested books for distraction, specifically "Where is Wally?". A special positioning for reading the book blocks visuals of the IV induction: *"The kids sit on the lab of a parent with crossed arms, looking at the book on one side, not seeing what you're doing on the other hand."* [P4]

3.2.4.4 Virtual Reality The majority of interviewees do not use VR because *"it's just too much time investment, and too much rely on the technology."* [P11] However, there is a common belief of 4/13 interviewees, that VR works in pre-school and younger school children (compare Fig. 21, orange bar): *"It's because of participation,* *with VR kids are engaged. It would be perfect for that age group that think bubbles are too childish, but they still want to participate. They are too used to TV and it's just looking at it, with VR they actually get to do something."* [P1]

3.2.4.5 TV Ten of 13 interviewees find TV distraction effective in children from 4 years to 13 years of age (see Fig. 21, dark blue bar), *"but it is not universal. It's often not positioned in the correct place."* [P11] According to 3/13 interviewees, TV's works best in younger children from 4 to 7 years. Also, it is mentioned to be more effective than the iPad in pre-school children. *"When they're focused on the TV right away when they walk in the room, then I can see that TV is probably going to work for this kid. But if you're telling them "hey look what's on the TV", and they haven't even looked up before, then I know TV is not going to be it."* [P8]
Usually, children can pick what they want to watch preoperatively, which most interviewees think is useful. *"For the younger ones it's always Paw Patrol, Thomas the Train, or Frozen."* [P3] With regard to teenagers, 2/13 participants mentioned that TV distraction is sometimes effective in teenagers but not used much in this age group. Two participants further criticized the use of screens in general (TV and iPad), because *"it's getting so far away from empathy and human kindness"* [P7], also *"a lot more parents don't want their kids having screen time, and then we're forcing it on them when they come in here"* [P13].

3.2.4.6 Verbal Verbal is the distraction technique of choice for 12/13 interviewees: *"For me it's definitely always verbal in all ages"* [P3] (see Fig. 21, green bar), and *"we just say different things with different ages."* [P11] Another interviewee explained: *"Just the fact that you're talking and they are listening, processing, even if you just keep talking about silly things is effective and they don't have time to get anxious, they are thinking about other things because they are trying to follow you."* [P9]
Interviewees further share the opinion that in older patients, especially teenagers, verbal distraction is the most appropriate technique. This has also been seen in the circle graph (see Fig. 20). Since they are mature enough to understand what will happen, they can see through the distraction. Thus, *"just explaining what you're going to do and some sort of verbal discussion, maybe distraction by the nurses and staff talking to them about what they're studying at school, or where they've been on vacation on"* [P5] is effective in keeping their mind off the induction.

3.2.5 Advice to novices

Participants were asked about what advice they would give to a new resident before their very first pediatric IV attempt. Most frequently mentioned advice categories were IV insertion advice (n=7), preparation advice (n=5), advice on handling the patient (n=5), and advice on handling the parents (n=4).
Themes emerged from cluster analysis with circle graphs (see Fig. 22 and Appendix Tab. 13): a) education (learn - feedback - level, sleep - adults), and b) technical skills (needle - movements - straw - exactly). Due to colour similarity, the theme distraction (resident - distraction) emerged. Parents were also considered as a theme. All correlation lines indicating relationships between the words share the same strength. Further analysis resulted in the collapsing of related themes into six main themes: education, parents, environment, child, practical approach, and technical skills (see Appendix, Fig. 28, blue boxes).

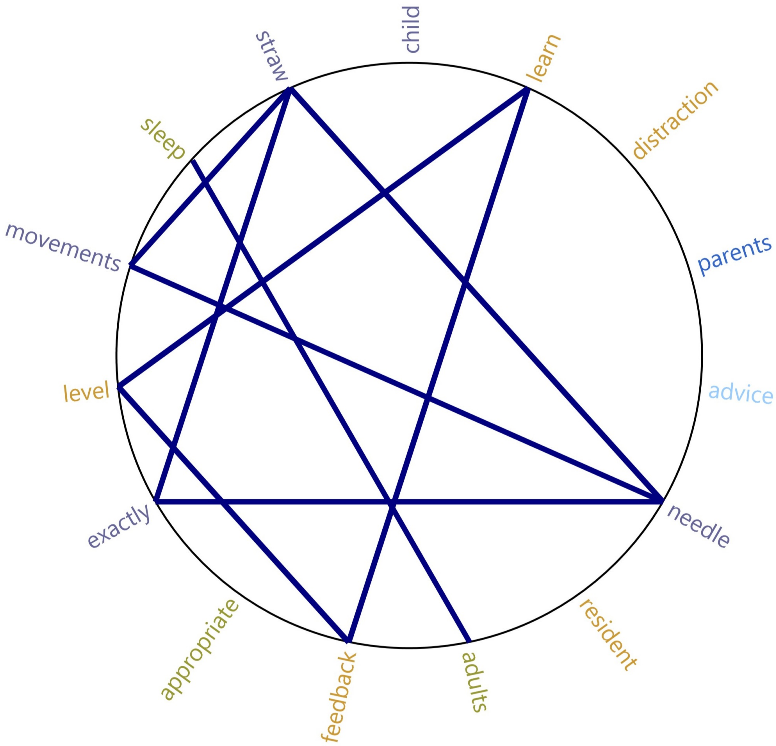

FIG. 22. Circle Graph Q4. The 20 most frequently used words on the perimeter, starting with child then going clockwise. Correlations with index <0.9 are suppressed in the visualization.

3.2.5.1 Education Advice on the educational aspect of IV insertion in awake pediatric patients was provided by 7/13 interviewees. Four of 13 interviewees recommended, to *"start with adults that are asleep, then go to awake adults, and then children, preferably asleep children."* [P3]. Three participants further emphasized that unlike adults, children may not hold their hand still. Thus, novices need to learn how to hold pediatric hands in order to *"have control"* [P10], which is considered crucial by 2/13 interviewees when it comes to sudden movements.
Two participants further recommended observing what other practitioners are doing differently: *"Go and watch a few different practitioners who are really good at their job and who are effective and have minimum movements. "* [P7] One interviewee suggested watching educational videos beforehand, to look at age-appropriate techniques, and see the physiological changes from younger to older patients.

3.2.5.2 Parents A total of 4/13 interviewees provided advice on how to handle the parents. Regarding the parents, 3/13 interviewees would recommend to explain to them beforehand what will happen during induction, *"so the expectation for parents is IV."* [P3] One interviewee would further emphasize to explain *"that they are part of it and cannot show anxiety."* [P6]

3.2.5.3 Environment Four of 13 interviewees gave advice on the environment during IV insertion. One interviewee underlined the importance of having the child in a position which optimizes access to the hand: *"Most key is having that hug that the parent does with the hand behind the back."* [P1] One participant emphasized the need for having assistance to immobilize the arm. P4 further recommended, to *"try to get the parents out as soon as possible."*

3.2.5.4 Child Child related advice to novices was provided by 3/13 participants. Two interviewees would recommend a new learner, to individualize the approach depending on the patient and the patient's age. For some needle phobic patients, one interviewee would advise to *enquoteshow them exactly what's going to happen to their body, and letting them touch and play with an IV cannula with the needle not there is exactly what they need.* [P7] Two participants would give the advice to *"talk soothingly"* [P13] to the patients during induction. One participant would emphasize the importance to recognize *"when it's not appropriate to have an IV induction and [...] recognizing there is other options, and making sure that the most appropriate one is being used in that case."* [P12]

3.2.5.5 IV insertion - Practical approach Advice to novices related to the practical approach was provided by all 13 interviewees. Six interviewees would suggest to optimize conditions prior to IV insertion. *"First of all, making sure you've got all your equipment ready to go and having it on hand, within reach."* [P5] When the patient is in the OR, one interviewee would recommend to *"take cream off quickly or even before they go in."* [P6] Two interviewees further provided the advice to *"take a vein that you're confident in getting in, always"* [P3] and to check for suitable insertion sites on both hands, because *"your best chance is your first chance"*. [P11] One participant would emphasize to apply *"the tourniquet as close to the vein as possible."* [P4]
"Be bold" [P2, P4], and *"go with confidence"* [P3, P13] is how 4/13 interviewees would encourage their new learners to approach awake IV induction in pediatric patients. P2 further emphasized that *"if the cream's not quite right and you're not bold, you've lost it."*
Avoiding delays was underlined by 4/13 interviewees. Two participants would emphasize to novices that it is important to get the IV cannulation done quickly before *"you've lost your window"* of opportunity. [P9]
Three interviewees advise new learners to have *"a good helper, someone who knows exactly what you're trying to do"* [P2] during IV cannulation, and to let someone else take care of the distraction so that they can *"concentrate on doing one thing rather than trying to do two things at once."* [P11]
Regarding the needle, 2/13 interviewees advise to not use the word 'needle', but to say 'drinking straw' instead: *"I try to give them something in their language that they can relate to and the reason it's a drinking straw is because that sounds maybe not really threatening and they're used to having a straw at home."* [P7] Another interviewee further suggests saying 'intravenous' instead. The participant also advised to *"don't ever show the child the needle"* [P1], and to keep it covered.
Three interviewees would advise novices to switch to inhalational induction if they are not successful within two cannulation attempts: *"I think if the IV doesn't work go to plan B very quickly, don't persist, because you might need an IV for something else after that and you have the option of doing your best. Don't ruin its confidence in IV, just go to plan B straight away."* [P4]

3.2.5.6 Technical skills Technical advice on IV cannulation was provided by 6/13 interviewees, and is explained in chronological order in which steps are performed. Advice is further categorized into the following three steps: a) holding of the hand, b) insertion, and c) steps to do in the vein.

Five interviewees referred to the holding of the patient's hand: *"Hold the hand like in a hand shake with you palm to palm, and tension the skin from the sides"* [P1], also *"you need to hold a firm grip, you need to be prepared for the pull-back"* [P13]. Next, 2/13 interviewees recommend to pull the skin back taut, in order to keep the vein pinned.

Two interviewees mentioned to give advice to novices on the process of IV inserting. One interviewee mentioned to recommend a safety IV to novices. Having a *"clear line of approach to the dorsal hand"* [P5] with the cannula directly in line with the vessel, were underlined by 2/13 interviewees. One interviewee also provided advice on the angle of approach: *"What I see residents do is that they are not going superficial enough in a child."* [P10] When inserting the catheter, one interviewee recommends *"to get in through the skin, and if you don't get into the vein straight away, just to stop and check at that point that you're still going the way you think you need to be going."* [P1]

Six interviewees provided advice on technical skills once the vein is cannulated. Two interviewees would emphasize to novices, that *"when you first get a flush your needle tip is in but your cannula is not."* [P9] For advancing of the cannula, both interviewees further advise to *"get as horizontal to the vessel as you can and advance a little bit further, so that you know for sure that the cannula is in as well as the needle tip."* [P5] One participant would then explain to use the needle as a trocar support for the cannula: *"Pull the needle back so that there's a gap between the needle and the cannula, and then slide the whole apparatus in as one."* [P5]

3.2.5.7 Ranking of most important advice to novices by BCCH pediatric anesthesiologists Of all aspects of advice provided by the interviewees, one attending anesthesiologist and co-investigator on the study synthesized the information to the five most important tips for successful awake IV placement in pediatric patients:

1. Apply topical anesthetic early and ensure it has enough time to work – at least 30 minutes for tetracaine and lidocaine, or 60 minutes for EMLA.

2. Ensure distraction is available and effective for the patient – their favorite television show or mobile/tablet game are common requests.

3. Patient and family should be familiarized with the process so expectations are clear (thus reducing anxiety), including an over the shoulder hug from parent in the OR to block visuals of the IV placement. Patient and family wishes should be honored when possible.

4. Have a low threshold to administer pharmacologic anxiolysis when needed, and/or to switch to inhalation induction if needle phobia is identified. Traumatizing the patient is to be avoided if at all possible.

5. Venipuncture in pediatrics is subtly different from adults – the veins are sometimes quite superficial yet surrounded by fatty subcutaneous tissue. Practice on adults first, then sleeping children, before attempting an awake IV start in pediatric patients.

4 Discussion

The initial discussion is structured in parallel to the methods and discussion. Next, interpretation of result, limitations and future work are outlined.

4.1 Key findings - Part A

The local BCCH IV induction bundle, with minimal use of anxiolytic premedication (6 %), was successful in 90 % of patients who required cannulation for planned IV induction. A majority of 90 % had no or only minimal reaction to IV insertion. Completely pain- and reaction-free IV insertion was achieved for 64 % of children. Identified predictors for success were older age of the patient and their behaviour at first encounter. IV inductions in young patients and/or patients with combative behaviour, when first encountered, were significantly more likely associated with failure than when attempted in older and/or calm patients. Our results suggest that IV induction of anesthesia for a large majority of patients is feasible, when implemented as an institutional strategy. Results of this audit further show that IV induction is possible without unduly traumatizing pediatric patients.

Kotiniemi and Ryhänen (1996) achieved a similar IV induction success rate of 90 %. Their study (n=29) took place in children between the ages two to seven years in a hospital where IV inductions were routinely performed by experienced providers. Success on first attempt was achieved in 26 cases (90 %), two patients needed two attempts, and one patient had four attempts. Demir and Inal (2017), found that in a pediatric clinic of a teaching and research hospital in Turkey, a first attempt success rate by experienced nurses was 47 % for patients between 3 - 18 years of age. However, it was not further stated whether IV induction was routinely used in this population in their institution.

Anxiolytic premedication use at BCCH, for only 6 % of patients, was much lower than what is reported for other institutions. Holm-Knudsen, Mckenzie, and Carlin (1998) reported rates of 33 % in patients from six months to 14 years of age in the Royal Children's Hospital in Melbourne, Australia. In their practice, premedication use was selectively based on the anesthesiologists' assessment of the child and the circumstances of the surgery and anesthesia. In patients with distressed preoperative behaviour, premedication was shown to reduce the incidence of distress at induction in approximately 50 % of cases, from 88 % to 45 % in six months to two year old patients, and 75 % to 32 % in three years to 14 year old patients. This was observed irrespective of the patient's age.

While Kotiniemi and Ryhänen (1996) stated that IV insertion may be associated with more anxiety during the induction, their study also showed that cannula placement was less distressing compared to inhalational induction when judging by patients' negative memories. This study revealed a 64 % pain- and reaction-free catheter placement, thus a majority of patient's did not feel the needle poke and may not have realized the IV cannula placement, or were able to ignore it given appropriate distraction, which further supports the findings of Kotiniemi and Ryhänen.

Holm-Knudsen, Mckenzie, and Carlin (1998) investigated factors causing distress at induction, while specifically investigating age, preoperative behaviour, and premedication. Distressed preoperative behaviour was shown to be a good predictor for distress at induction. In the context of the IV induction audit findings, distressed behaviour preoperatively or at induction of anesthesia resulted in a decreased success rate of IV cannulation. It was further found by Holm-Knudsen et al. that "it is of great value to have a calm and compliant child during the induction", which agrees with the results of the IV induction audit.

Finally, Kontiniemi and Ryhänen mentioned that anticipated very difficult venous access or extremely anxious and uncooperative patients constitute an exception to the routine practice of IV induction in pediatric patients. This is consistent with the observed practice at BCCH.

4.2 Key findings - Part B

Factors for IV induction success identified in semi-structured interviews included a) effective distraction, b) preparing the family to expect IV induction, c) the presence of a calm parent and an over the shoulder hug, d) perioperative team support, e) effective use of local analgesic cream, f) selectivity in consideration of IV induction appropriateness, g) speed at induction, and an h) overall tailored approach to the individual patient. Barriers included a) needle phobia, b) anxious or uncooperative patients, c) ineffective use of analgesic cream, and d) unfavourable anatomy. Distraction techniques highly depended on the age and developmental stage of the patient. Verbal distraction was used in all age groups by interviewees, bubbles were favourably used in pre-school children when permitted by hospital policy, and iPad and TV were not considered universally effective. Participants advised novices to practice on adults and sleeping children first, before attempting an IV start in an awake child.

A recent study by Balanyuk et al. (2018) compared the effectiveness of verbal distraction, such as talking about hobbies or interests, a holiday, or the town the person lives in, and a pharmacological technique (EMLA cream) in reducing the patient's pain perception caused by catheter placement. However, the study was conducted in adults and EMLA cream was applied for 15 minutes only. It found that distraction techniques significantly reduced perception of pain compared to the application of EMLA cream. Balanyuk et al. explained that distraction should be age appropriate and reflect the patient's interests and preferences if possible. Further it was stated that with effective distraction the patient's attention is focused on an alternative stimulus and is distracted from anxiety and fear. Those findings are similar to the results gained in our semi-structured interviews.

Ramgolam et al. (2018) reported that IV induction may not be suitable for every patient, such as needle-phobic patients, or patients with a history of difficult IV access, and that those patients may benefit from inhalational induction. Local practice seems to agree with these suggestions. In our study, the importance of knowing when IV induction may not be appropriate was emphasized by anesthesiologists in order to avoid distress and/or trauma of pediatric patients. Special consideration of the approach would also be given to patients with fear of needles or difficult IV access. Previous inductions that have not gone well in other institutions, which may not routinely provide IV inductions to pediatric patients, were not generally seen as a contraindication to IV induction, since the BCCH approach differs from that of other institutions.

Both the role of the anesthesiologist and equipment were described by Kotiniemi and Ryhänen (1996). It was mentioned that skill, experience, and practice of the anesthesiologist as well as high quality IV cannulas suitable for very small veins were required for success of the cannula placement. All of these facilitators mentioned by Kotiniemi and Ryhänen were also uncovered by the IV induction audit, however the latter was considered a minor factor in our findings.

4.3 Overall interpretation

The observed success rate of 90 % for IV cannulation in less than two attempts was higher than expected prior to conducting the study, and is likely higher than success rates for other institutions. One reason for this result may be that IV cannulation was performed by an expert physician, here a pediatric anesthesiologists, compared to an allied health worker, such a phlebotomist. Depending on the country and the institution, IV cannulation is often performed by phlebotomists, registrars, or nurses who have certainly undergone additional training, but may not always be as experienced as an anesthesiologist. Anesthesiologists at BCCH perform IV cannulation for a majority of their patients and usually between one to eight times in a day. This training already starts in medical school, and is routinely applied during residency and fellowship training.
Another reason for a 90 % success rate may be that anesthesiologists at BCCH are very selective in patients who are suitable for IV induction. This can be seen in 100 % success rates of some anesthesiologists, and responses during semi-structured interviews. Many anesthesiologists would only start an IV if they feel confident they'll succeed. If the anesthesiologist does not consider IV induction to be suitable for a particular patient, institutionally there is still room to switch to inhalational induction as an alternative method of induction. However, the threshold of when to switch to an alternative induction method varies by provider. Some anesthesiologists would not attempt IV unless they are confident in succeeding, whereas others may still attempt it. Of those who attempt it, some anesthesiologists may switch to an alternative method after a single failed attempt, while others may try a second time. This practice is also very much dependent on patient related factors and can't be generalized. Residents are usually allowed to try once, and if unsuccessful only a further time for older children. Selection bias may play a role in the number of attempts granted to a resident. Limiting the attempts of residents may increase the success of IV cannulation in less than two attempts, which was the primary outcome of this study.

The study has further proven that the BCCH IV induction bundle worked in 90 % of patients despite minimal anxiolytic premedication use (6 % of patients). This is considered unique and of important novel, since most other centers routinely administer premedication to a majority of their patients. One outlier for anxiolytic premedication (47 % of cases) was observed in this study; this participant was a new attending physician who had not trained at BCCH. Depending on where participants were trained or had practiced before, they all developed individual methods to successfully conduct IV inductions at our institution. Thus, approaches to induction varied highly at BCCH. Variability in practice was not only shown by the use of anxiolytic premedication, also parental presence and distraction techniques as both are individual choices that not only depend on the patient, but also significantly on the provider. However, the study has demonstrated that the BCCH IV induction bundle works despite the variability in practice patterns.

Even though the over the shoulder hug provided by a parent was only explicitly mentioned by two participants, it is considered a major factor for success. The reason for this is not only to have the patient in a convenient position to insert the cannula but also the reassuring and calming effect of the hug, and the visual blockage of the insertion site; thus having the patient to sit still and preventing the patient from startling. The latter two aspects were mentioned to be factors for success by many interview participants without partially attributing those to the effect of the special hug.

Two factors were seen to play a large role in getting IV induction as the default mechanism accepted by families. Assessing and approaching the parental expectation preoperatively is one of them. As shown in the results, it is highly important to have the parent(s) on board with the plan. Thus, having parental expectations set on IV induction right from the preoperative meeting in ACU enables the anesthesiologist to work with the parent(s), which facilitates successful IVinduction.
The second factor was the preparation of the patient. This not only includes effective use of local analgesic cream, but also age-appropriate distraction of the pediatric patient to achieve cooperation at IV induction.

Finally, by tailoring identified significant facilitators for success to BCCH pediatric patients, it is likely that the success rate of IV cannulation in less than two attempts will further increase. Additionally, the results of the IV induction audit may further increase acceptance of this technique as an institutional strategy by other institutions.

4.4 Limitations

Limitations are split into study design limitations, and limitations regarding the study conduct.

4.4.1 Study design limitations

A major limitation of the study design was a mechanism to ensure all eligible cases were captured, or at least to flag missing documentation easily in order to provide corrective feedback. Incomplete case capture was particularly pronounced for emergency cases and unsedated MRI scans, which often remained unknown to the researchers. This resulted in an inaccurate capture rate of OR data collection, and a lower response rate of data collection forms, when compared to administrative (case booking) data obtained retrospectively. Having a mechanism to keep track, case capture would have allowed for timely and personalized feedback to participants, and increased communication regarding ineligible cases would have reduced a potentially inflated number of missed cases, both having the potential for improved accuracy of the overall capture rate. However, despite the shortcomings in sampling, the overall sample size captured is large (almost 1,000 cases from a variety of settings) and diverse in nature, thus ensuring representative results for the BCCH practice.

The incompleteness of data collection forms could have been avoided by using electronic data capture, at the point of care with immediate or timely feedback requesting completion of missed items, when they were still possible to be recovered. Incomplete data were an obstacle to data analysis, particularly for optimization approaches used to simplify the logistic regression model since these routines were not robust against missing data and required the use of complete case analysis. However, for a given variable, missing information was limited to a small number of cases each. Thus, one can conclude that the overall result of the study was not affected by the absence.

Besides autism and anxiety no other medical conditions that could influence the patient's behaviour at first provider encounter and immediately before IV induction were captured. To maintain a prospective and simple study design, additional effort to identify such conditions in the patient chart was intentionally avoided. However, given the overall high success rate, the impact of potentially undetected risk factors for IV induction failure, is perceived to be low.

Pain on propofol injection was assessed by the provider and not reported by the patient. In some cases it may have been difficult to distinguish pain caused by the injection of propofol from upset behaviour caused by the overall experience of induction or hospitalization. Thus, judgment of the anesthesiologist may vary. For an upset patient at propofol injection, some anesthesiologists may have indicated pain on injection, whereas others may have traced the patient's behaviour back to factors unrelated to the propofol injection. An additional field on the data collection form for indeterminable cases would have improved the accuracy of this result.

4.4.2 Study conduct limitations

For semi-structured interviews, selection bias may have occurred for the choice of interview participants. Participants were chosen depending on their practice of induction methods. For participants with similar performance availability may have also had an impact on the decision. However, since almost half of the staff pediatric anesthesiologists participated in the interviews, the impact on the results is considered to be low.

4.5 Future work

A secondary analysis of collected data could for example also look at the proportion of autistic patients (n=90) in the study and at BCCH. Subgroup analysis may reveal differences of IV induction characteristics in the non-autistic population compared to autistic patients. Subgroup analysis may also be conducted by the individual years of practice of fellows and residents, to evaluate a training/competency effect. Since the distraction technique of blowing bubbles was identified as the most popular distraction technique by interviewees, a randomized controlled trial evaluating the effectiveness of blowing bubbles in comparison with TV as a non-interactive distraction technique, in a certain age group, may further prove its effectiveness.

Results of this study should also be supplemented with ethnographic observations of senior attending anesthesiologists teaching IV induction in children to new learners, such as new clinical fellows or new anesthesia resident. By assessing how IV induction is taught, additional critical facilitators for its success may be identified.

5 Conclusion

The BCCH IV induction bundle was successful in 90 % of cases, with 90 % of children showing no or minimal reaction to the IV placement. Predictors for success included older patient age and calm patient behaviour at first encounter. The success of the BCCH IV induction bundle depends on a combination of many facilitators, such as parental expectation, patient preparation, team support, effective distraction, topical cream placement, calm OR environment, placing the hand out of sight using the "parental hug", and skills of the provider.
Future audits would benefit from electronic data capture and near real-time feedback on form completion. The results of this study suggest that IV induction of anesthesia is a viable option for the majority of children, and thus TIVA is a feasible anesthetic strategy, without causing significant child distress.

Bibliography

Agnor, Ross C., Nancy Sikich, and Jerrold Lerman (1998). "Single-breath Vital Capacity Rapid Inhalation Induction in Children: 8% Sevoflurane versus 5% Halothane". In: *Anesthesiology* 89.8, pp. 379–384.

Balanyuk, I. et al. (2018). "Distraction technique for pain reduction in peripheral venous catheterization: Randomized, controlled trial". In: *Acta Biomedica* 89.6, pp. 55–63. ISSN: 25316745. DOI: 10.23750/abm.v89i4-S.7115.

Basadonna, Giacomo (2016). *AccuVein Vein Illumination Device (AV400) Improves First Attempt Success Rate for IV Placement in Obese Patients*. URL: https://www.accuvein.com/assets/Clinical-Studies-Umass-Obese.pdf (visited on 2019).

Batchelor, Hannah K and John F Marriott (2015). "Formulations for children : problems and solutions". In: *British Journal of Clinical Pharmacology* iii. DOI: 10.1111/bcp.12268.

Bithal, Parmod (2014). "Anaesthetic considerations for evoked potentials monitoring". In: *Journal of Neuroanaesthesiology and Critical Care* 01.01, pp. 002–012. ISSN: 2348-0548. DOI: 10.4103/2348-0548.124832.

Bond, Mary et al. (2016). "First do no harm: Pain relief for the peripheral venous cannulation of adults, a systematic review and network meta-analysis". In: *BMC Anesthesiology* 16.1, pp. 1–11. ISSN: 14712253. DOI: 10.1186/s12871-016-0252-8. URL: http://dx.doi.org/10.1186/s12871-016-0252-8.

Bortone, Luciano, Luca La Colla, and Marinella Astuto (2016). "Preoperative Preparation". In: *Perioperative Medicine in Pediatric Anesthesia*. Ed. by Marinella Astuto and Pablo M Ingelmo. Chap. 3, pp. 21–37. ISBN: 2281-1796. DOI: 10.1007/978-3-319-21960-8.

Burkle, Christopher M et al. (2004). "A Historical Perspective on Use of the Laryngoscope as a Tool in Anesthesiology". In: *Anesthesiology* 100.4, pp. 1003–1006. ISSN: 00033022. DOI: 10.1097/00000542-200404000-00034.

Canadian Institutes of Health Research, Natural Sciences and Engineering Research Council of Canada, and Social Sciences and Humanities Research Council of Canada (2014). "Ethical Conduct for Research Involving Humans". PhD thesis. ISBN: 9781100254739. URL: http://www.pre.ethics.gc.ca/pdf/eng/tcps2-2014/TCPS{_}2{_}FINAL{_}Web.pdf.

Chandler, John R. et al. (2013). "Emergence delirium in children: A randomized trial to compare total intravenous anesthesia with propofol and remifentanil to inhalational sevoflurane anesthesia". In: *Paediatric Anaesthesia* 23.4, pp. 309–315. ISSN: 11555645. DOI: 10.1111/pan.12090.

Chidambaran, Vidya, Andrew Costandi, and Ajay D'Mello (2015). "Propofol: A Review of its Role in Pediatric Anesthesia and Sedation". In: *CNS Drugs* 29.7, pp. 543–563. ISSN: 11791934. DOI: 10.1007/s40263-015-0259-6.

Child Life Council and Committee on Hospital Care (2006). "Child Life Services". In: *Pediatrics* 118.4, pp. 1757–1763. ISSN: 0031-4005. DOI: 10.1542/peds.2014-0556.

Costarino, Andrew T and John J Downes (2005). "Pediatric anesthesia historical perspective". In: *Anesthesiology Clinics of North America* 23.4, pp. 573–595. ISSN: 08898537. DOI: 10.1016/j.atc.2005.08.005.

Demir, Duygu and Sevil Inal (2017). "Does the Use of a Vein Visualization Device for Peripheral Venous Catheter Placement Increase Success Rate in Pediatric Patients?" In: *Pediatric Emergency Care* 00.00, pp. 1–6. ISSN: 15351815. DOI: 10.1097/PEC.0000000000001007.

Desousa, Kalindi Anil (2016). "Pain on". In: *Indian Journal of Pharmacology* 48.6, pp. 617–623. DOI: 10.4103/0253-7613.194845.

Dorrington, K. L. and W. Poole (2013). "The first intravenous anaesthetic: How well was it managed and its potential realized?" In: *British Journal of Anaesthesia* 110.1, pp. 7–12. ISSN: 14716771. DOI: 10.1093/bja/aes388.

Dziak, John J et al. (2019). "Sensitivity and specificity of information criteria". In: *Briefings in Bioinformatics* January. DOI: 10.1093/bib/bbz016.

Freeman, Jv and Michael J Campbell (2007). "The Analysis of Categorical Data : Fisher'S Exact Test". In: *Scope* 33.5, pp. 11–12. ISSN: 01495992. DOI: 10.2337/dc09-1830.. URL: https://www.sheffield.ac.uk/polopoly{_}fs/1.43998!/file/tutorial-9-fishers.pdf{\%}0Ahttp://www.sheffield.ac.uk/polopoly{\%}7B{_}{\%}7Dfs/1.43998!/file/tutorial-9-fishers.pdf{\%}5Cnhttp://www.sheffield.ac.uk/polopoly{_}fs/1.43998!/file/tutorial-9-fishers.pdf.

Gaynor, J and J M Ansermino (2016). "Paediatric total intravenous anaesthesia". In: *BJA Education* 16.11, pp. 369–373. ISSN: 20585349. DOI: 10.1093/bjaed/mkw019.

Glantz, Stanton A (1992). *Primer of Biostatistics*. 3rd ed. McGraw-Hill, p. 440. ISBN: 978-0078641152.

Goff, D. A. et al. (2013). "Resource Utilization and Cost of Inserting Peripheral Intravenous Catheters in Hospitalized Children". In: *Hospital Pediatrics* 3.3, pp. 185–191. ISSN: 2154-1663. DOI: 10.1542/hpeds.2012-0089.

Harless, Jeff, Ramesh Ramaiah, and Sanjay M. Bhananker (2014). "Pediatric airway management". In: *International Journal of Critical Illness & Injury Science* 4.1, pp. 65–70. DOI: 10.4103/2229-5151.128015.

Harris, Paul A et al. (2009). "Research Electronic Data Capture (REDCap) - A metadata-driven methodology and workflow process for providing translational research informatics support". In: *Journal of Biomedical Informatics* 11.2, pp. 377–381. ISSN: 1348-5504. DOI: 10.1016/j.jbi.2008.08.010.Research.

Harty, Eoin (2011). "Inserting peripheral intravenous cannulae - tips and tricks". In: *Update in Anesthesia* 27.1, pp. 22–26. URL: https://www.researchgate.net/publication/288201031{_}Inserting{_}peripheral{_}intravenous{_}cannulae{_}-{_}Tips{_}and{_}tricks.

Holm-Knudsen, R J, I M Mckenzie, and J B Carlin (1998). "Distress at induction of anesthesia in children. A survey of incidence, associated factors and recovery characteristics". In: *Pediatric Anesthesia* 8.5, pp. 383–392.

Inal, Sevil and Duygu Demir (2018). "Impact of Peripheral Venous Catheter Placement With Vein Visualization Device Support on Success Rate and Pain Levels in Pediatric Patients Aged 0 to 3 Years". In: *Pediatric Emergency Care* 00.00, pp. 1–7. ISSN: 0749-5161. DOI: 10.1097/pec.0000000000001493.

Kacmarek, Robert M (2011). "The Mechanical Ventilator: Past, Present, and Future". In: *Respiratory Care* 56.8, pp. 1170–1180. DOI: 10.4187/respcare.01420.

Kain, Zeev N. (2006). "Psychological Aspect of Pediatric Anesthesia". In: *Smith's Anesthesia for Infants and Children*. Ed. by Etsuro K Motoyama and Peter J Davis. 7th ed. Philadelphia: Mosby Elsevier. Chap. 7, pp. 241–253. ISBN: 978-0323-02647-5.

Kelly, Fiona E et al. (2014). “Intensive care medicine is 60 years old: the history and future of the intensive care unit”. In: *Clinical Medicine* 14.4, pp. 1–8. DOI: 10.1142/9781848163898_0001.

King, Nigel (2004). “Using Interviews in Qualitative Research”. In: *Essential Guide to Qualitative Methods in Organizational Research Qualitative Research Diaries*. Ed. by Catherine Cassell and Gillian Symon. SAGE Publications Ltd. Chap. 2, pp. 11–22. ISBN: 0761948880. DOI: http://dx.doi.org/10.4135/9781446280119.n2. URL: http://books.google.com/books?hl=en{\&}lr={\&}id=fuKzv0-zzEwC{\&}pgis=1.

Kleinbaum, David G and Mitchel Klein (2002). *Logistic Regression: A Self-Learning Text*. Ed. by K Dietz et al. 2nd ed., p. 517. ISBN: 0387953973.

Kotiniemi, Leena H and Pauli T Ryhänen (1996). “Behavioural changes and children’s memories after intravenous, inhalation and rectal induction of anesthesia”. In: *Pediatr* 6.3, pp. 201–207.

Lauder, Gillian R (2015). “Total intravenous anesthesia will supercede inhalational anesthesia in pediatric anesthetic practice”. In: *Paediatric Anaesthesia* 25.1, pp. 52–64. ISSN: 14609592. DOI: 10.1111/pan.12553.

Lenhardt, Rainer et al. (2002). “Local warming and insertion of peripheral venous cannulas: single blinded prospective randomised controlled trial and single blinded randomised crossover trial”. In: *Bmj* 325.7361, p. 409. ISSN: 09598138. DOI: 10.1136/bmj.325.7361.409.

Lerman, Jerrold, Charles J Coté, and David J Steward (2016a). “Anatomy and Physiology”. In: *Manual of Pediatric Anesthesia*. 7th ed. Springer. Chap. 2, pp. 9–38. ISBN: 978-3-319-30684-1.

— (2016b). “Clinical Pharmacology”. In: *Manual of Pediatric Anesthesia*. 7th ed. Springer. Chap. 3, pp. 39–77. ISBN: 978-3-319-30684-1. DOI: 10.1007/978-3-319-30684-1.

— (2016c). “Foundations of Pediatric Anesthesia”. In: *Manual of Pediatric Anesthesia*. 7th ed. Springer. Chap. 1, pp. 1–8. ISBN: 978-3-319-30684-1. DOI: 10.1007/978-3-319-30684-1.

Mai, Christine L and Charles J Coté (2012). “A history of pediatric anesthesia: A tale of pioneers and equipment”. In: *Paediatric Anaesthesia* 22.6, pp. 511–520. ISSN: 11555645. DOI: 10.1111/j.1460-9592.2012.03828.x.

Mai, Christine L et al. (2014). “The development of a specialty: An interview with Dr. Mark C. Rogers, a pioneering pediatric intensivist”. In: *Paediatric Anaesthesia* 24.9, pp. 912–918. ISSN: 14609592. DOI: 10.1111/pan.12497.

McCormack, Jon G. (2007). “Total intravenous anaesthesia in children”. In: *CPD Anaesthesia* 9.2, pp. 63–69. ISSN: 14662922. DOI: 10.1016/j.cacc.2008.09.005. URL: http://dx.doi.org/10.1016/j.cacc.2008.09.005.

McIntosh, Michele J and Janice M Morse (2015). “Situating and Constructing Diversity in Semi-Structured Interviews”. In: *Global Qualitative Nursing Research* 2, pp. 1–12. ISSN: 2333-3936. DOI: 10.1177/2333393615597674.

Morgan Jr., G Edward, Maged S Mikhail, and Michael J Murray (2008a). “Pediatric Anesthesia”. In: *Clinical Anesthesiology*. 4th ed. McGraw-Hill. Chap. 44, pp. 922–939. ISBN: 0-07-110515-8.

— (2008b). “The Practice of Anesthesiology”. In: *Clinical Anesthesiology*. 4th ed. McGraw-Hill. Chap. 1, pp. 1–16. ISBN: 0-07-110515-8.

Motoyama, Etsuro K and Peter J Davis (2006). “Special Characteristics of Pediatric Anesthesia”. In: *Smith’s Anesthesia for Infants and Children*. Ed. by Etsuro K Motoyama and Peter J Davis. 7th ed. Philadelphia: Mosby Elsevier. Chap. 1, pp. 3–11. ISBN: 978-0323-02647-5.

Motoyama, Etsuro K, Brian J Gronert, and Gavin F Fine (2006). "Induction of Anesthesia and Maintenance of the Airway in Infants and Children". In: *Smith's Anesthesia for Infants and Children*. Ed. by Etsuro K Motoyama and Peter J Davis. 7th ed. Philadelphia: Mosby Elsevier. Chap. 10, pp. 319–331. ISBN: 978-0323-02647-5.

Nafiu, Olubukola O. et al. (2010). "Comparing peripheral venous access between obese and normal weight children". In: *Paediatric Anaesthesia* 20.2, pp. 172–176. ISSN: 11555645. DOI: 10.1111/j.1460-9592.2009.03198.x.

O'Connor, Sean et al. (2016). "Remifentanil and propofol undergo separation and layering when mixed in the same syringe for total intravenous anesthesia". In: *Paediatric Anaesthesia* 26.7, pp. 703–709. ISSN: 14609592. DOI: 10.1111/pan.12917.

Passmore, Steven R, Bernadette Murphy, and Timothy D Lee (2014). "The origin, and application of somatosensory evoked potentials as a neurophysiological technique to investigate neuroplasticity". In: *The Journal of the Canadian Chiropractic Association* 58.2, pp. 170–183. ISSN: 0008-3194. URL: http://www.ncbi.nlm.nih.gov/pubmed/24932021{\%}0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC4025087.

Provincial Health Services Authority (2019). *Research Ethics Approval*. URL: http://www.phsa.ca/researcher/ethics-approvals/research-ethics-approval.

QSR International Pty Ltd (2019a). *About cluster analysis*. URL: http://help-nv11.qsrinternational.com/desktop/concepts/about{_}cluster{_}analysis.htm (visited on 05/10/2019).

— (2019b). *Run a Text Search query*. URL: http://help-nv11.qsrinternational.com/desktop/procedures/run{_}a{_}text{_}search{_}query.htm (visited on 05/10/2019).

— (2019c). *Run a Word Frequency query*. URL: http://help-nv11.qsrinternational.com/desktop/procedures/run{_}a{_}word{_}frequency{_}query.htm (visited on 05/10/2019).

— (2019d). *What is NVivo*. URL: https://www.qsrinternational.com/nvivo/what-is-nvivo (visited on 05/10/2019).

Ramakrishna, H K (2005). "Tests of Significance". In: *Medical Statistics*. Vol. 34. 878. Springer. Chap. 5, pp. 35–66. ISBN: 9789811019227. DOI: 10.1016/s0140-6736(02)79573-1.

Ramgolam, Anoop et al. (2018). "Inhalational versus IV Induction of Anesthesia in Children with a High Risk of Perioperative Respiratory Adverse Events". In: *Anesthesiology* 128.6, pp. 1065–1074. DOI: 10.1097/ALN.0000000000002152. URL: http://links.lww.com/ALN/B725..

Robinson, Daniel H and Alexander H Toledo (2012). "Historical development of modern anesthesia". In: *Journal of Investigative Surgery* 25.3, pp. 141–149. ISSN: 08941939. DOI: 10.3109/08941939.2012.690328. arXiv: arXiv:1009.1876v5.

Saha, Chiranjeev (2012). "Capnography, Second Edition". In: *Anesthesiology* 116.4, pp. 744–745. ISSN: 0003-3022. DOI: 10.1097/aln.0000000000001745.

Sánchez, Hernández A et al. (2013). "How much do our children suffer during anesthesia induction?" In: *European Journal of Anaesthesiology* 30.51, p. 20.

ScienceDirect (2019). *Rank Sum Test*. URL: https://www.sciencedirect.com/topics/medicine-and-dentistry/rank-sum-test.

Scott, Jeanette and Paul A Barker (2009). "How did the Macintosh laryngoscope become so popular?" In: *Pediatric Anesthesia* 19, pp. 24–29. ISSN: 00074977. DOI: 10.1111/j.1460-9592.2009.03026.x.

Shaikh, Safiya Imtiaz et al. (2016). "Postoperative nausea and vomiting: A simple yet complex problem". In: *Anesthesia, Essays and Researches* 10.3, pp. 388–396. DOI: 10.4103/0259-1162.179310.

Smith, Robert M and Mark A Rockoff (2006). "History of Pediatric Anesthesia". In: *Smith's Anesthesia for Infants and Children*. Ed. by Etsuro K Motoyama and Peter J Davis. 7th ed. Philadelphia: Mosby Elsevier. Chap. 35, pp. 1173–1190. ISBN: 978-0323-02647-5.

Soltanizadeh, Sinor, Thea H Degett, and Ismail Gögenur (2017). "Outcomes of cancer surgery after inhalational and intravenous anesthesia : A systematic review". In: *Journal of Clinical Anesthesia* 42, pp. 19–25. DOI: 10.1016/j.jclinane.2017.08.001.

Song, Jae W and Kevin C Chung (2010). "Obersvational Studies: Cohort and Case-Conrtol Studies". In: *Plast Reconstr Surg* 126.6, pp. 2234–2242. ISSN: 1529-4242. DOI: 10.1097/PRS.0b013e3181f44abc.Observational. URL: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2998589/.

Szmuk, Peter et al. (2013). "The VeinViewer vascular imaging system worsens first-attempt cannulation rate for experienced nurses in infants and children with anticipated difficult intravenous access". In: *Anesthesia and Analgesia* 116.5, pp. 1087–1092. ISSN: 00032999. DOI: 10.1213/ANE.0b013e31828a739e.

Tallarida, R J (2001). "Drug synergism: Its Detection and Applications". In: *The Journal of pharmacology and experimental therapeutics* 298.3, pp. 865–72. ISSN: 0022-3565. URL: http://www.ncbi.nlm.nih.gov/pubmed/11504778.

Tariq, Shema and Jenny Woodman (2013). "Using mixed methods in health research". In: *JRSM Short Reports* 4.6, p. 204253331347919. ISSN: 2042-5333. DOI: 10.1177/2042533313479197. URL: http://journals.sagepub.com/doi/10.1177/2042533313479197.

The MathWorks (2019). *What is MATLAB?* URL: https://www.mathworks.com/discovery/what-is-matlab.html.

The University of British Columbia (2015). *BC Clinical Research Informed Consent From Guide and Template*. URL: https://ethics.research.ubc.ca/clinical-research-ethics/creb-forms-templates.

Tobias, Joseph D. and Marc Leder (2011). "Procedural sedation: A review of sedative agents, monitoring, and management of complications". In: *Saudi Journal of Anaesthesia* 5.4, pp. 395–410. DOI: 10.4103/1658-354X.87270.

UBC C&W Research Ethics Board (2014). *University of British Columbia / Children's and Women's Research Ethics Board - Terms of References*. URL: http://www.phsa.ca/research/Documents/c-w-reb-tor-july11-2014-final.pdf.

Van Der Woude, Olga C.P. et al. (2013). "The effectiveness of a near-infrared vascular imaging device to support intravenous cannulation in children with dark skin color: A cluster randomized clinical trial". In: *Anesthesia and Analgesia* 116.6, pp. 1266–1271. ISSN: 00032999. DOI: 10.1213/ANE.0b013e31828e5bde.

Wu, Zhi-Fu et al. (2018). "Propofol-based Total Intravenous Anesthesia Is Associated with Better Survival Than Desflurane Anesthesia in Colon Cancer Surgery". In: *Anesthesiology* 129.5, pp. 932–941.

Appendix

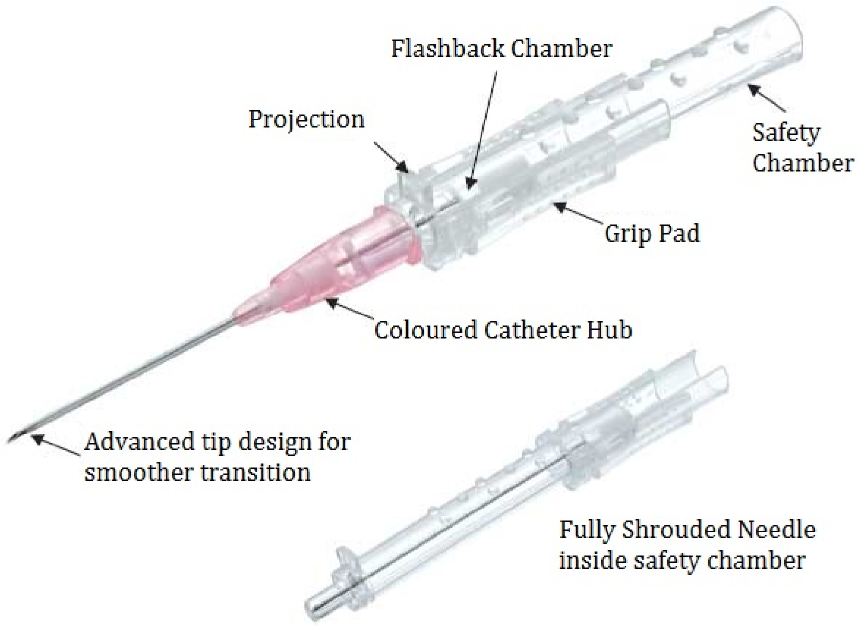

FIG. 23. Set-up of a safety IV cannula
http://www.neotecmedical.com/products.html#cannula8-tab

	Advantages	Disadvantages
Clinical	Reduced postoperative nausea and vomiting (PONV) Reduced airway reactivity Less perioperative respiratory adverse events Reduced emergence delirium (ED) Neuroprotection Improved survival rate of adult cancer patients Reduced cancer recurrence Reduced incidence of postoperative metastasis	Pain on intravenous cannulation Pain on injection of propofol Risk of bacterial contamination Risk of propofol-related infusion syndrome (PRIS)
Practical	Readily titratable Maintenance of spontaneous ventilation (SV) No risk to volatile exposure of operating room staff No interference with sensory evoked potential Transportable Does not require anesthetic machine Enables out of operating room procedures Speed and good quality of recovery High turnover of cases	Requirement for IV access Difficulty in finding peripheral vein access Lack of reliable EEG measurement Potential for disconnected or interstitial IV access
Other	Avoid seizure potential associated with sevoflurane Lower costs of maintenance No atmospheric pollution	Environmental impact: Plastic waste due to the use of syringes and tubing Waste of unused propofol Syringes and tubing may be expensive

TAB. 2. Advantages and disadvantages of TIVA

IV Induction: Efficacy of intravenous induction of general anesthesia at BC Children's Hospital Data Collection Sheet

Instructions: Please (circle), ✗ check, and/or fill **each** question

Vascular access in place = Complete *after* Q 8
Planned inhalation induction = Complete *after* Q 11
Planned IV induction = Please complete *all* questions

---

1. Anesthesiologist: ____________________

2. Date: __________

Patient Demographics

3. Age: _____

4. Sex: **M / F**

5. Anxiety documented on slate? **Y / N**

6. Autism documented on slate? **Y / N**

7. Has previously been anesthetized? **Y / N**

Planning

8. Vascular access already in place? **Y / N**
- If yes, **form complete.**

9. Anxiolytics given? **Y / N**
- If yes, drug(s) given:
  - □ Midazolam
  - □ Dexmed
  - □ Ketamine
  - □ Other _______________

10. Topical anesthetic applied? **Y / N**
- If yes, time applied (eg 13:05): __________
- Mark all used:
  - □ Ametop
  - □ Lidocaine
  - □ EMLA
  - □ Pain Ease (at time of IV attempt)

11. Planned inhalation induction? **Y / N**
- If yes, **mark reason & form complete**:
  - □ Parent / Child request
  - □ Anticipated difficult IV
  - □ Lack of patient cooperation in ACU
  - □ Insufficient time for local anesthetic
  - □ Training an IH induction
  - □ Provider preference
  - □ Other _______________

Environment during IV attempt

12. Room IV attempted in:
- □ PR _____
- □ MRI
- □ ACU

13. Child behaviour when encountered:
- □ Calm
- □ Distressed but cooperative
- □ Combative

14. Child behaviour immediately before IV insertion:
- □ Calm
- □ Distressed but cooperative
- □ Combative

15. Parent/Guardian present? **Y / N**

IV Placement

16. Distraction technique(s) used:
- □ TV
- □ iPad
- □ Bubbles
- □ VR
- □ Verbal
- □ None

17. 1st IV Attempt:
- Time attempted (eg 14:23): __________
- *Reaction to skin puncture: None / Slight / Severe
- *Reaction to vein puncture: None / Slight / Severe
- Provider:
  - □ Staff
  - □ Fellow
  - □ AA
  - □ Resident; Year _____
    - ▪ Fellow / Resident time @ BCCH: _____ weeks

18. 2nd IV Attempt (if applicable):
- *Reaction to skin puncture: None / Slight / Severe
- *Reaction to vein puncture: None / Slight / Severe
- Provider:
  - □ Staff
  - □ Fellow
  - □ AA
  - □ Resident; Year _____
    - ▪ Fellow / Resident time @ BCCH: _____ weeks

19. Total # of IV insertion attempts: _____

20. IV induction successful? **Y / N**
- If yes, provider on successful attempt:
  - □ Staff
  - □ Fellow
  - □ AA
  - □ Resident; Year _____
    - ▪ Fellow / Resident time @ BCCH: _____ weeks
- If yes, any pain on propofol injection? **Y / N**

Done! Thank-You ☺

Important Field! Please be as accurate as possible

*Reaction Definitions:
- None: May notice, but not bothered
- Slight: Facial grimace, withdrawal of hand
- Severe: Cries, screams, vigorous withdrawal of hand

IV Induction Data Collection (H18-02649)
Version 2.0 December 18, 2018 Page **1** of **1**

FIG. 24. Data Collection Form, Version 2. Logical approach of completion along sequential numbering

Data Collection Sheet

Date ___________________

IV Induction: Efficacy of intravenous induction of general anesthesia at BC Children's Hospital

Patient Demographics

Age _____ | Sex **M / F** | Anxiety documented on slate? **Y / N** | Anesthesiologist ___________

Has previously been anesthetized? **Y / N** | Time (clock) topical applied ________ | Autism? **Y / N**

Planning

Planned inhalational induction? **Y / N**

if **yes**, mark reason:

- ☐ Parent / Child request
- ☐ Anticipated difficult IV
- ☐ Lack of patient cooperation in ACU
- ☐ Insufficient time for local anesthetic
- ☐ Training an IH induction
- ☐ Provider preference
- ☐ Other ________________________

Anxiolytics given? **Y / N** if **yes**, Drug(s):

- ☐ Midazolam
- ☐ Dexmed
- ☐ Ketamine
- ☐ Other ________

Topical anesthetic applied? **Y / N**

if **yes**, mark all used:

- ☐ Ametop
- ☐ Lidocaine
- ☐ EMLA
- ☐ Pain Ease (at time of IV attempt)

Environment (during IV attempt)

Room IV attempted in: ☐ PR *or* ☐ MRI *or* ☐ ACU | Time (clock) of 1st IV attempt

Child behavior when encountered:

- ☐ Calm
- ☐ Distressed but cooperative
- ☐ Combative

Behavior immediately before IV insertion:

- ☐ Calm
- ☐ Distressed but cooperative
- ☐ Combative

Parental presence? **Y / N**

IV Placement (if applicable)

Distraction technique(s) used: ☐ TV ☐ iPad ☐ Bubbles ☐ VR ☐ Verbal ☐ None

1st Attempt

Reaction* to skin puncture: None / Slight / Severe

Reaction* to vein puncture: None / Slight / Severe

Provider: ☐ Staff ☐ Fellow ☐ AA

☐ Resident Year _____

Fellow/Resident time at BCCH: _____ weeks

2nd Attempt

Reaction* to skin puncture: None / Slight / Severe

Reaction* to vein puncture: None / Slight / Severe

Provider: ☐ Staff ☐ Fellow ☐ AA

☐ Resident Year _____

Fellow/Resident time at BCCH: _____ weeks

Total # of IV insertion attempts _____ | Pain on propofol injection? **Y / N**

IV induction successful? **Y / N** if **yes**, provider on successful attempt:

☐ Staff ☐ Fellow ☐ AA ☐ Resident Year _____

Fellow/Resident time at BCCH: _____ weeks

Thank-you!

***Reaction definitions:** None

Slight (facial grimace, withdrawl of hand)

Severe (cries, screams, vigorous withdrawal of hand)

IV Induction Data Collection (H18-02649)
Version 1 October 22nd, 2018 Page 1 of 1

FIG. 25. Data Collection Form, Version 1. Visual approach of completion from top to bottom. No field for 'Vascular access already in place?' provided.

Age Group	REDCap Category Label	Age [Years]
<28 days	1	$\frac{14\ days}{365\ days} = 0.04$
28 days to <4 months	2	$\frac{2.5\ months}{12\ months} = 0.21$
4 months to <7 months	3	$\frac{5.5\ months}{12\ months} = 0.46$
7 months to <12 months	4	$\frac{9.5\ months}{12\ months} = 0.79$
1 year	5	1.5
2 years	6	2.5
3 years	7	3.5
4 years	8	4.5
5 years	9	5.5
6 years	10	6.5
7 years	11	7.5
8 years	12	8.5
9 years	13	9.5
10 years	14	10.5
11 years	15	11.5
12 years	16	12.5
13 years	17	13.5
14 years	18	14.5
15 years	19	15.5
16 years	20	16.5
17 years	21	17.5
18 years	22	18.5
> 18 years	23	19.5

TAB. 3. Conversion of patient age from categorical age (Age Group, left) to numerical age in years (Age (years), right) for calculations.

	Overall	Q1	Q2	Q3	Q4
Word frequency query					
Displayed Words	50	20	20	15	20
Min. Length	4	2	2	2	5
Grouping	With stemmed word	With stemmed words	With stemmed words	With synonyms	With stemmed words
Additional settings for circle graph display					
Cluster	NA	8	9	6	6
Similarity	NA	0.7 - 1	0.6 - 1	0.6 - 1	0.9 - 1

TAB. 4. Customized settings for circle graph display. Settings shown for queries on overall interview data and data of Q1-Q4 separately.

LETTER	WORDS
a	a a1 able about above act actual actually advantage after again against all almost already also always am an and anesthesia any applied appreciate appreciation are aren't around as ask asking assist at attitude away
b	babies back backup bad badly be because been before being below best better better' between big biggest bit bits blow blowing board both boy bring bringing but by bystander
c	can can't cannot can't care carefully caring carry carrying case certain chances charged children choice close closer come comes coming confidence confident connect consider contribute convince coping could couldn't course covered create
d	deal dealing decide decided definitely depend dependence dependent depending depends did didn't difference different differs disordered do does doesn't doing don't done don't down during
e	each easy else engage engaging enough especially even everything except
f	few find fine first fixed for forcing from funny further fuss
g	game general generally get gets getting give giving go god going good grab great group groups guard
h	had hadn't hair hall handle handles hands happen happened happening happens has hasn't have haven't having he he'd he'll he's heavily he'd he'll help helped helpful helping helps her here here's hers herself he's him himself his how how's
i	i i'd i'll i'm i've i'd idea identify identifying if important in independent initiate installation interviews into involve involved is isn't it it's its it's itself
j	joke judgment just
k	keep kid kiddy kids kind kinds know knowing knows
l	language last less let let's lie life like liked likely likes little long look looked looking looks lot lots love
m	make makes making man manage management many mask mask' mass matter matters maybe me mean might mind mindful minor minute minutes modes moment more most move moved movement much multiple mustn't my myself
n	need needed needs never no nor not notice now number
o	obviously of off often okay old older on once one ones only operating operator or other others ought our ours ourselves out over own
p	part participate particularly passing path patient patients people perhaps person personal personally pick picked place plan pose possibility possible possibly present presents pretty probably process processing pull put puts putting
q	question questions quite
r	raise raising rather real really reason record rely required right routinely
s	said same saw say says second seconds see seeing seems seen semi separate set setting shall shame shan't she she'd she'll she's she'd she'll she's short should shouldn't show side silly single sit sitting situations so some somebody someone something sometimes soon sort space stage stand start status stay staying still stop strong strongly structured stuff such sure switch
t	take takes taking tell tend than that that's the their theirs them themselves then there there's these they they'd they'll they're they've they'd they'll they're they've thing things think thinking this those thought three through timely times to today too train tried trouble try trying tuck turn two
u	under understand understanding understands until up upon us use used useful using usually
v	very
w	walk wally want wanted wants was wasn't way way' ways we we'd we'll we're we've we'd well we'll were we're weren't we've what what's whatever what's when where where's whether which while who who's whole whom who's whose why why's will with without won't wondering won't work worked working works would wouldn't
x	/
y	year years you you'd you'll you're you've you'd you'll your you're yours yourself yourselves you've
z	/

TAB. 5. Customized Stop Word List. Words excluded from NVivo analysis

	OVERALL	%	PLANNED IV INDUCTION	%	PLANNED IH INDUCTION	%	VA ACCESS IN PLACE	%
N	984		562	57	263	27	159	16
DEMOGRAPHICS								
Female	413 / 981	42	234 / 560	42	111 / 263	42	68 / 158	43
Median [IQR] Age (years) *	6.5 [3.5-13.0]		8.5 [3.5-13.5]		4.5 [2.5-9.5]		6.5 [2.5-14.5]	
Anxiety documented	101 / 981	10	49 / 560	9	45 / 263	17	7 / 158	4
Autism	90 / 941	10	46 / 540	9	36 / 252	14	8 / 149	5
Previously anesthetized	515 / 934	55	262 / 528	50	154 / 254	61	99 / 151	65
ANXIOLYTICS								
Anxiolytics given *	68 / 798	9	31 / 548	6	37 / 250	15	NA	
Midazolam	50 / 68	74	21 / 31	68	29 / 36	80		
Dexmedetomidine	4 / 68	6	2 / 31	6	2 / 36	6		
Ketamine	1 / 68	1	1 / 31	3	0 / 36	0		
Other	14 / 68	21	8 / 31	26	6/ 36	17		
CREAM PLACEMENT								
Topical cream applied	721 / 804	90	549 / 561	98	172 / 243	71	NA	
Ametop	390 / 676	58	307 / 525	59	83 / 151	55		
Lidocaine	224 / 676	33	170 / 525	32	53 / 151	35		
EMLA	53 / 676	8	38 / 525	7	15 / 151	10		
Pain Ease Spray	95 / 676	14	94 / 525	18	1 / 151	1		
* Statistically significant variables with P-values < 0.05								

TAB. 6. Demographics of the overall study population, and patients with planned IV induction, planned IH induction, and vascular access in place

	PLANNED IV INDUCTION	%	IV SUCCESS	%	IV FAILURE	%
N	562		506 / 562	90	56 / 562	10
DEMOGRAPHICS						
Female	234 / 560	42	213 / 504	42	21 / 56	38
Median [IQR] Age (years) *	8.5 [3.5-13.5]		8.5[4.5-13.5]		5.5 [3.0-9.5]	
Anxiety documented	49 / 560	9	46 / 504	9	3 / 56	5
Autism	46 / 540	9	41/ 488	8	5 / 52	10
Previously anesthetized	262 / 528	50	235 / 479	49	27 / 49	55
ANXIOLYTICS						
Anxiolytics given *	31 / 548	6	24 / 494	5	7 / 54	13
Midazolam	21 / 31	68	15 / 24	63	6 / 7	86
Dexmedetomidine	2 / 31	6	2 / 24	8	0 / 7	0
Ketamine	1 / 31	3	1 / 24	4	0 / 7	0
Other	8 / 31	26	7 / 24	29	1 / 7	14
CREAM PLACEMENT						
Topical cream applied	549 / 561	98	497 / 505	98	52 / 56	93
Ametop	307 / 525	59	277 / 479	58	30 / 46	65
Lidocaine	171 / 525	33	158 / 479	33	13 / 46	28
EMLA	38 / 525	7	35 / 479	7	3 / 46	7
Pain Ease Spray	94 / 525	18	85 / 479	18	9 / 46	20
Median [IQR] Time topical applied (min)	60 [44-90]		60 [43-90]		60 [44-75]	
ENVIRONMENT						
OR	448 / 561	80	405 / 505	80	43 / 56	77
MRI	87 / 561	15	75 / 505	15	12 / 56	21
ACU	26 / 561	5	25 / 505	5	1 / 56	2
Parental presence	486 / 549	89	439/495	89	47/54	87
BEHAVIOUR AT FIRST ENCOUNTER *						
Calm	462 / 557	83	421 / 501	84	41 / 56	73
Distressed but cooperative	76 / 557	14	66 / 501	13	10 / 56	18
Combative	19 / 557	3	14 / 501	3	5 / 56	9
BEHAVIOUR IMMEDIATELY BEFORE IV INDUCTION *						
Calm	401 / 557	72	370 / 501	74	31 / 56	55
Distressed but cooperative	127 / 557	23	110 / 501	22	17 / 56	31
Combative	29 / 557	5	21 / 501	4	8 / 56	14
DISTRACTION						
TV	214 / 552	39	196 / 497	39	18 / 55	33
iPad	23 / 552	4	19 / 497	4	4 / 55	7
Bubbles	57 / 552	10	48 / 497	10	9 / 55	16
Verbal	312 /552	57	277 / 497	56	35 / 55	64
None	67 / 552	12	60 / 497	12	5 / 55	9
REACTION TO SKIN AND VEIN PUNCTURE						
None	342 / 537	64	332 / 488	68	10 / 49	20
Slight	142 / 537	26	121 / 488	25	21 / 49	43
None or slight	484 / 537	90	453 / 488	93	31 / 49	63
Severe	53 / 537	10	35 / 488	7	18 / 49	37
ATTEMPTS						
Median [IQR] Nr. of attempts	1 [1-1]		1 [1-1]		1 [1-2]	
Pain on propofol injection	NA		43 / 468	9	NA	
* Statistically significant variables with P-values < 0.05						

TAB. 7. Overview of planned IV induction, IV success and IV failure study population.

	Median	IQR
Overall factors		
Anxiety	8.3	3.2 – 15.3
Anxiolytics given	5.8	3.7 – 17.0
Planned IH induction	26.7	21.3 – 45.8
Topical applied	92.0	85.7 – 95.1
Success rates		
IV success	94.7	89.5 – 100.0
Painless IV	67.8	52.0 – 75.0
Slight reaction	25.7	14.7 – 33.3
Painless or slight reaction	94.2	83.8 – 100.0
Severe reaction	5.9	0.0 – 16.3
Distraction techniques		
Parental presence	89.3	83.3 – 100.0
TV	38.5	26.2 – 48.1
iPad	1.3	0.0 – 6.5
Bubbles	5.3	0.0 – 12.4
Verbal	51.3	38.5 – 72.5
None	7.7	2.0 – 19.1

TAB. 8. Median and interquartile range (IQR) of practice variability of attending anesthesiologists.

Rank	Word	Count	Rank	Word	Count
1	child	298	26	experience	20
2	distraction	85	27	ipad	19
3	parents	83	28	team	19
4	talk	54	29	skill	17
5	induction	53	30	teenagers	17
6	attempt	52	31	watch	16
7	factors	49	32	anxious	15
8	successful	48	33	problem	15
9	time	45	34	sleep	15
10	needle	44	35	adult	14
11	bubbles	40	36	preparation	14
12	cream	36	37	calm	13
13	feel	36	38	conversation	13
14	room	35	39	medical	13
15	anesthetist	32	40	phobia	13
16	family	32	41	playing	13
17	vein	32	42	effective	12
18	techniques	30	43	focus	12
19	nurse	28	44	teaching	12
20	hold	26	45	video	12
21	hand	24	46	autistic	11
22	resident	24	47	honest	11
23	barriers	23	48	quickly	11
24	verbal	22	49	screen	11
25	advice	21	50	toddlers	11

TAB. 9. Overall interview data. The 50 most frequently used words by interviewees.

Rank	Word	Count	Rank	Word	Count
1	child	130	11	factor	14
2	parents	47	12	skill	13
3	distraction	40	13	experience	11
4	anesthetist	22	14	key	11
5	family	22	15	preparation	11
6	time	21	16	talking	11
7	team	19	17	communicate	10
8	successful	17	18	holding	10
9	veins	17	19	nurses	10
10	cream	16	20	hugging	10

TAB. 10. Q1: The 20 most frequently used words by interviewees to describe factors for success.

FIG. 26. Q1: Factors for IV cannulation success (green). Major themes are illustrated in blue.

Rank	Word	Count	Rank	Word	Count
1	child	64	11	distraction	9
2	needle	26	12	nurses	9
3	cream	22	13	time	9
4	parent	20	14	anesthetist	7
5	induction	19	15	barrier	7
6	anxious	13	16	feel	7
7	factors	13	17	reasonable	7
8	phobia	13	18	veins	7
9	attempts	10	19	difficult	6
10	talking	10	20	distressed	6

TAB. 11. Q2: The 20 most frequently used words by interviewees to describe barriers.

Rank	Word	Count	Rank	Word	Count
1	child	75	9	screens	16
2	verbal	51	10	playing	13
3	tv	51	11	time	11
4	bubbles	38	12	interactive	10
5	ipad	28	13	mom	10
6	distraction	24	14	parents	10
7	age	23	15	vr	10
8	teenagers	18			

TAB. 12. Q3: The 15 most frequently used words by interviewees to describe distraction techniques.

Rank	Word	Count	Rank	Word	Count
1	child	31	11	feedback	5
2	distraction	9	12	appropriate	4
3	learn	9	13	exactly	4
4	parents	8	14	experience	4
5	induction	7	15	level	4
6	needle	6	16	movements	4
7	watch	6	17	quickly	4
8	advice	6	18	sleep	4
9	resident	6	19	straw	4
10	adults	5	20	cannula	3

TAB. 13. Q4: The 20 most frequently used words by interviewees to describe advice to novices.

FIG. 27. Q2: Factors posing a barrier to IV cannulation success (green). Major themes are illustrated in blue.

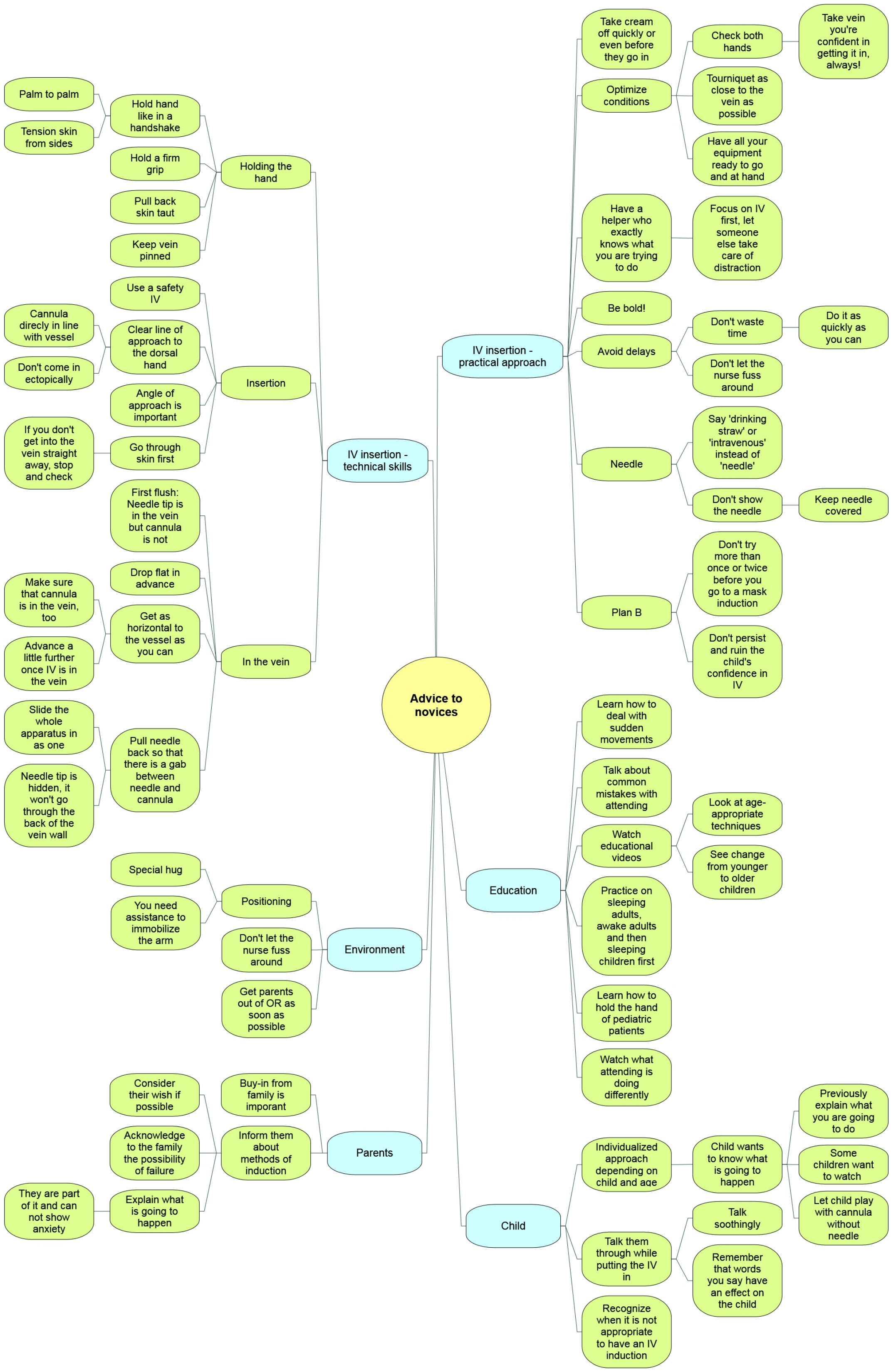

FIG. 28. Q4: Advice to novices (green). Major themes are illustrated in blue

.